ERDC/CERL SR-14-11

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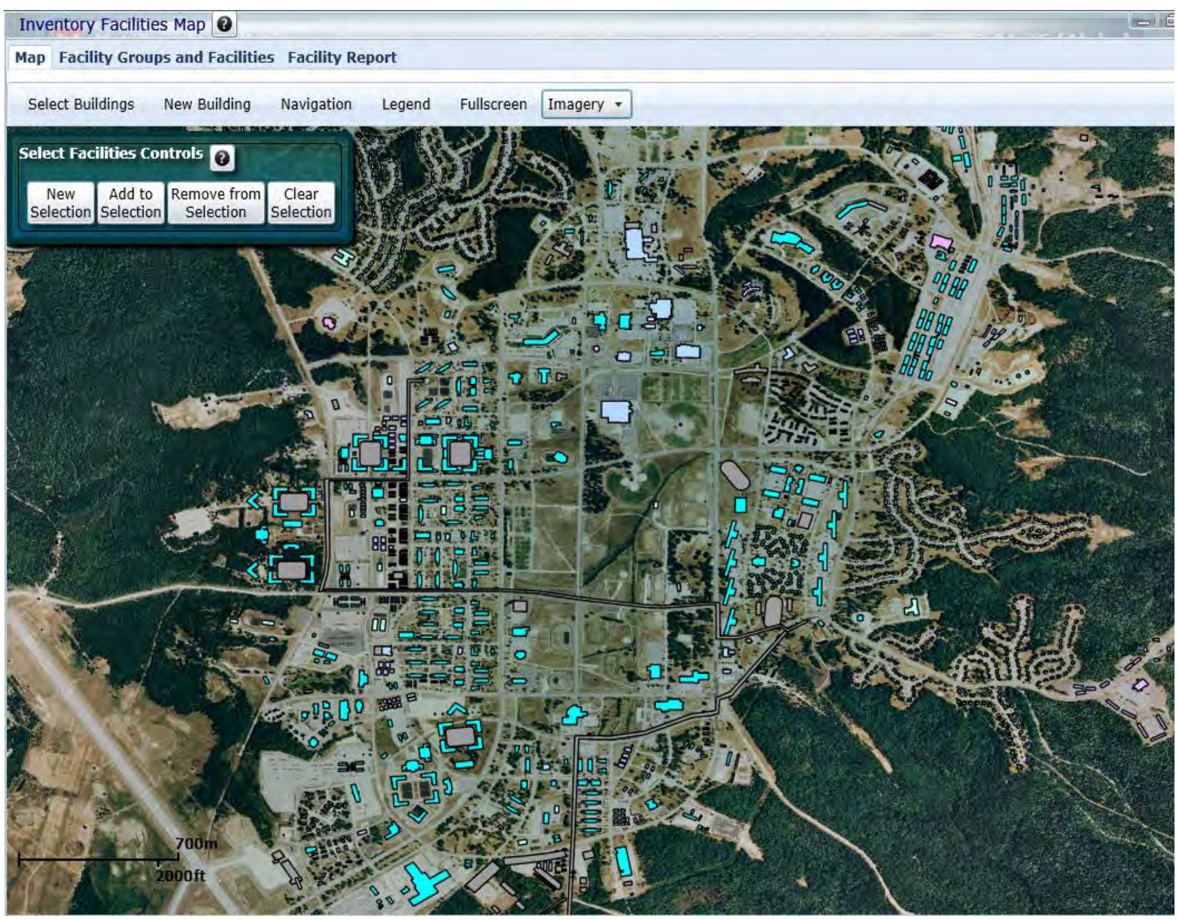
Center for the Advancement of Sustainability Innovations (CASI)

Fiscal Year 2013 Net Zero Energy–Water–Waste Portfolio for Fort Leonard Wood

Annette L. Stumpf, Michael P. Case, Matthew M. Swanson, Benjamin P. Barnes, Susan J. Bevelheimer, Marianne Choi, Stephen D. Cosper, Laura Curvey, Jorge Flores, Noah Garfinkle, Dick L. Gebhart, Elisabeth M. Jenicek, Richard J. Liesen, Thomas R. Napier, and Giselle Rodriguez

December 2014



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Construction Engineering Research Laboratory
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Champaign, IL 61822

Final report

Prepared for U.S. Army Garrison Fort Leonard Wood
Fort Leonard Wood, MO 65473

Under Project 3H92KF, "Integrated Energy, Water, and Waste Portfolio for Fort Leonard Wood"

Abstract

The Army focused its organizational sustainability on the development of Net Zero waste, energy, and water at its installations. Fort Leonard Wood faces constraints on critical resources. As part of its strategic sustainability vision, Fort Leonard Wood seeks to meet Army Net Zero objectives.

The objective of this project was to develop an integrated portfolio of cost-effective and mission-appropriate strategies, approaches, and technologies to help Fort Leonard Wood implement its Net Zero strategic vision for energy, water, and waste.

The U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) was consulted to help Fort Leonard Wood identify and evaluate strategies, methods, and technologies to support the Army Net Zero objectives. ERDC-CERL performed assessments to baseline energy, water, and waste systems at Fort Leonard Wood. Because these systems are highly interrelated, they were best evaluated concurrently and optimized in an integrated effort.

Energy, water, and waste teams estimated changes in requirements, population, energy and water use, and waste generation over a 25 year time period. Each team then established alternatives to show how improved practices, sustainable development and high performance buildings could reduce waste generation, energy, and water use.

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Preface

This study was conducted for the Plans, Analysis, and Integration Office (PAIO) at U.S. Army Garrison Fort Leonard Wood under MIPR 10234387, Project 3H92KF, “Integrated Energy, Water, and Waste Portfolio for Fort Leonard Wood.” The technical monitor was Mark Premont, PAIO Chief, Fort Leonard Wood.

The work was performed by the Engineering Process Branch (CF-N) of the Facilities Division (CF), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). The ERDC-CERL Project Managers were Annette L. Stumpf and Susan J. Bevelheimer, CEERD-CF-N. At the time of publication, Donald K. Hicks was Chief, CEERD-CF-N; L. Michael Golish was Chief, CEERD-CF; and Frank R. Holcomb was the Director of the Center for Advancement of Sustainability Innovations (CASI). The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti, and the Director was Dr. Ilker Adiguzel.

This work would not have been possible without the direct contributions of the military and civilian personnel at Fort Leonard Wood and the Maneuver Support Center of Excellence. Their input is the basis for this report, and the named authors who have recorded that input are deeply indebted to their dedicated efforts. The authors also recognize the valuable input and time given to help this plan by ERDC-CERL researchers who selected Fort Leonard Wood as a case study for other research projects and collaborated with our team during the planning and development process.

COL Jeffrey R. Eckstein was the Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

1 Introduction

1.1 Background

Fort Leonard Wood is a large, complex military installation that trains 80,000 – 90,000 military personnel and civilians each year. It is home to the three Army schools: the U.S. Army Chemical, Biological Radiological and Nuclear School, the U.S. Army Engineer School, and the U.S. Army Military Police School. It has a Training and Doctrine Command (TRADOC) mission and supports a large Forces Command (FORSCOM) presence with deployable units, including the 4th Maneuver Enhancement Brigade (which is headquartered on the installation). Fort Leonard Wood is also hosts DoD truck driver training and has a large international student detachment representing more than 120 nations.

Like all other U.S. military installations, Fort Leonard Wood faces constraints on critical resources. Concerns include the security of U.S. energy imports; the reliability, security, and resiliency of energy and water infrastructure; water and energy interruptions; energy price volatility; and the effects of climate change. Of specific urgency, due to a change in the relationship between Fort Leonard Wood and its previous utility supplier, the installation must quickly develop a plan to purchase and/or produce enough energy to meet its projected demands. In order to control costs, this plan must include measures to reduce energy use.

The Army has focused its organizational sustainability on the development of Net Zero waste, energy, and water at its installations. A Net Zero energy installation is an installation that produces as much energy on site as it uses, over the course of a year. A Net Zero water installation limits its consumption of freshwater resources and returns water back to the same watershed so not to deplete the groundwater and surface water resources of that region in quantity and quality over the course of a year. The Net Zero water strategy balances water availability and use to ensure sustainable water supply for years to come. A Net Zero waste installation is an installation that reduces, reuses, and recovers waste streams, converting them to resource values with zero landfill over the course of a year. The components of Net Zero solid waste start with reducing the amount of waste generated, re-purposing waste, maximizing recycling of waste stream to reclaim recyclable and compostable materials, recovery to generate energy as a by-product of waste reduction, with disposal being non-existent.

As part of its strategic sustainability vision, Fort Leonard Wood seeks to meet Army Net Zero objectives.

Army Directive 2014-02, *Net Zero Installations Policy*, issued 28 Jan 2014 reinforces Fort Leonard Wood's effort to achieve its strategic sustainability vision.

The information provided should help Fort Leonard Wood decision-makers compare and evaluate feasible options to identify its best long-term profile that will keep its resource use costs low and provide secure energy with a decreased impact on natural resources.

The purpose of this project was to collect and analyze baseline data for water and waste and conduct energy modeling and analysis of metering data to develop an integrated portfolio of cost-effective and appropriate strategies, approaches and technologies to help Fort Leonard Wood implement its strategic vision.

1.2 Objective

The objective of this project was to develop an integrated portfolio of cost-effective and mission-appropriate strategies, approaches, and technologies to help Fort Leonard Wood implement its Net Zero strategic vision for energy, water, and waste.

1.3 Approach

The U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) was consulted to help Fort Leonard Wood to identify and evaluate strategies, methods, and technologies that will support the Army Net Zero objectives. ERDC-CERL performed assessments to baseline energy, water, and waste systems at Fort Leonard Wood. Because these systems are highly interrelated, they are best evaluated concurrently and optimized in an integrated effort.

A portion of the work was performed using an ERDC-CERL research product, the Net Zero Planner, (Case, et al. 2014) to help achieve an installation-scale understanding of its energy system. This tool addresses topics such as

- building loads and clusters
- load reductions and energy savings
- application of renewable energy and new technologies
- smart grids
- power generation options
- distributed versus central plants
- solar thermal and solar hot water
- ground-source heat pumps
- tri-generation and co-generation heating and cooling options, etc.

The results of the analyses will be used to build a supportable business case for a mix of technologies and load reduction as the basis for a secure and sustainable Net Zero Energy–Water–Waste portfolio.

A Net Zero Energy assessment (electricity, heating, and cooling requirements) was performed. Approximately 60 categories of facility were identified, and energy models were adapted for many of them. Energy-metering data and energy models were used to develop energy-use intensity (EUI) statistics and benchmarks for selected facility type.

A Net Zero Water assessment was performed to identify where water is currently being used, and to determine the most promising strategies for conservation. As the Net Zero Planner is further developed to model water usage and the impacts of new technologies or system improvements, ERDC-CERL will add data and information compiled to the Net Zero Planner to document and refine options.

A Net Zero Solid Waste assessment addressed material utilization, conservation, and landfill diversion in support of Fort Leonard Wood's Net Zero Waste goals. It included waste-stream characterization and evaluation of "reduce–recycle–reuse" opportunities to decrease the installation's waste-disposal requirement. The material-utilization assessment included a survey of World War II-era and "rolling-pin" barracks buildings in terms of deconstruction feasibility, including methods, take-offs of recoverable and recyclable materials, and issues that would either facilitate or constrain deconstruction. The project team surveyed local and regional markets, deconstruction services, used-material outlets, and recycling facilities. Potential project-delivery approaches were explored, and issues in contracting provisions and specifications were identified.

ERDC-CERL is using the Engineering Knowledge Online (EKO) portal to capture the compiled baseline information and provide overall knowledge management capability for the portfolio.

1.4 Scope

Previous work

Fort Leonard Wood developed their Initial Integrated Strategic Sustainability Plan (ISSP) in 2010- 2011, which was published as a report in May 2012. ERDC-CERL SR-12-7 "Initial Integrated Strategic Sustainability Plan for Fort Leonard Wood" http://acwc.sdp.sirsi.net/client/search/asset/1008500 serves as a roadmap for Fort Leonard wood to continually adapt and improve its support systems to meet future demands.

The goals in the plan are ambitious and aggressive. Infrastructure, energy, water and waste related goals and strategic objectives are described below. This research effort must support Fort Leonard Wood teams in working towards their goals.

ERDC-CERL researchers used the results of the ISSP process to frame the research accomplished during this project, and worked closely with Fort Leonard Wood Goal Team members to help them achieve the Strategic Goals developed during the ISSP visioning.

Fort Leonard Wood core business areas

Six Core Business Areas or ISSP Goal Teams were identified to represent the processes at which the Garrison must be successful to satisfy customers and fulfill its missions for higher headquarters. They are

- Caring for Military, Civilians and Families
- Community Engagement
- Infrastructure (and Energy)
- Mission Services
- Training Lands, Ranges, and Facilities
- Workforce Development.

This project primarily supports the Infrastructure and Energy Goal Team, but ERDC-CERL researchers are active participants in quarterly meetings with all six ISSP Goal Teams.

Strategic Goal 1: Sustainable development and redevelopment at Fort Leonard Wood

Six Strategic Goals were developed during the ISSP process and this research effort directly supports Strategic Goal 1: Sustainable development and redevelopment at Fort Leonard Wood. Details are shown below:

Objective 1.1: Buildings in Campus setting that employ high-performance and adaptable systems to progressively reduce the use of nonrenewable resources.

Objective 1.2: Efficient use and management of energy and water that is provided from cost-competitive, secure, and renewable sources.

Objective 1.3: By 2035, develop new and modernize existing facilities to perform at net-zero with respect to energy, water, and waste while also providing a high quality of life and adaptable work environment.

Objectives

Detailed Objectives for Goal #1 are presented in table 1 through 3.

Table 1. Objective 1.1 – Building system standards.

Objective 1.1: Buildings in Campus setting that employ high-performance and adaptable systems to progressively reduce the use of non-renewable resources.	
Description: A community of smartly placed buildings in a campus setting that best supports the mission, which will occur while the following takes place: • Minimizing on-post vehicle use; • Reducing the loss of training land to cantonment area development; • Taking advantage of on-post renewable power generation; • Using distributed energy micro-grids; and • Maximizing accessibility to services and creating a pedestrian-friendly FLW community.	
Lead Organization: DPW	**Requirements:** IR1-4, EN2-1, EN2-2, EN2-3, EO 13514 §2(g)(i), EO 13514 §2(g)(vii), EISA §438, EO 13514 [§2(g)(iv)], EO13514, §2(g)(v), IR3-1, IR3-2, IR3-3, IR3-4, IR5-1, EO 13514 § 2(g)(vi).

<table>
<tr><th colspan="2">Objective 1.1: Buildings in Campus setting that employ high-performance and adaptable systems to progressively reduce the use of non-renewable resources.</th></tr>
<tr><td>Leading Measure(s):
• Updated Master Plan that institutionalizes “campus” development pattern
• Plan for repurposing exiting facilities into campus footprint</td><td>Lagging Measure(s):
• Restoration Backlog as a percentage of total inventory value
• Quality Facility Condition Index (FCI) Rating (Restoration Backlog as percentage of total inventory value)
• Square footage of repurposed facilities to meet deficits</td></tr>
<tr><td colspan="2">Target(s):
• Update Master Plan by 4Q FY13
• Complete Master Plan Programmatic Environmental Assessment
• Beginning in 2011 all major new facilities will be constructed within approved development zones
• Survey and plan for eliminating old, underutilized facilities</td></tr>
<tr><td colspan="2">FTEs Required:
• 1.2 FTE to support sustainable development and transportation FY11–36

Funding Required:
• $500K in FY11 to develop sustainable master plan (visioning) and IDG revision
• $550K in FY12 Capital Improvement Strategy (Facilities Baseline), and storm water plan
• $250K in FY13 for transportation plan
• $250K in FY13/14</td></tr>
</table>

Table 2. Objective 1.2 – Energy management.

<table>
<tr><th colspan="2">Objective 1.2: Efficient use and management of energy and water that is provided from cost-competitive, secure, and renewable sources.</th></tr>
<tr><td colspan="2">Description: Institutionalize energy and water savings by using conservation procedures and technologies throughout FLW. FLW heats primarily with natural gas which is a non-renewable source. There are also cost and security issues to consider with this energy source. FLW will develop an energy production and management portfolio that will:
• Provide a mix of purchased and self-produced, conventional and renewable energy sources;
• Explore and pursue on-site power production that will support development of sustainable power generation and use patterns;
• Be integrated into designed facilities that can use recovered heat from energy production
• Exploit renewable on-post power sources like bio-mass, solar, waste-to-heat, and co-generation;
• Integrate micro-grids into future development as well as improved and efficient transmission technologies; and
• Support the evolution of Fort Leonard Wood to a net-zero Installation.
• Reaching the goal of efficient use of energy (and water) must include education/outreach to all Soldiers, Families, civilians, and contractors.</td></tr>
<tr><td>Lead Organization: DPW Energy Manager</td><td>Requirements: EN3-2, EN3-3, EPAct 2005 §103, EPAct 2005 §203, EISA §431, EO13514§2(a)(i), EO 13514§2(f)(iv), EN1-3, EN3-1, EO 13514§2(f)(iv)</td></tr>
</table>

<table>
<tr><th colspan="2">Objective 1.2: Efficient use and management of energy and water that is provided from cost-competitive, secure, and renewable sources.</th></tr>
<tr><td>Leading Measure(s):
• Increase use of renewable power purchase/use to meet or exceed targets established under most aggressive requirement
• Increase efficiency of power transmission
• Percentage of key positions with energy and water management accountability in their job performance objectives
• Develop and integrate comprehensive energy and water master plans into the Master Plan
• Percentage of facilities with advanced meters
• Percentage of buildings connected to a utility monitoring and control system
• Percentage of facilities audited for energy and water savings annually
• Percentage of audit recommendations implemented annually</td><td>Lagging Measure(s):
• Security of sources (number of sources, number of connections to grid)
• Percentage of power used that is from renewable sources
• Unit cost(s) of power ($ per MBtu)
• Percentage reduction in energy consumption (density –MBtu per square foot)
• Percentage reduction in water consumption (density gallons per square foot)</td></tr>
<tr><td>Leading Target(s):
• All facilities metered for water and energy use by 2020
• All facilities audited for energy and water use reduction options by 2015
• Facilities then monitored on a schedule once every 4 years.</td><td>Lagging Targets:
In compliance with EPAct 2005 §203, increase renewables by:
• 3% in FY2007–2009
• 5% in FY 2010–2012
• 7.5% in FY 2013</td></tr>
<tr><td colspan="2">FTEs Required: 0.7 FTE in 3Q FY11, approximately 3.0 FTE in 4Q FY11-3Q FY12, approximately 1.0 FTE in 4Q FY12-4Q FY15, 2.7 FTE in FY16, 0.5 FTE in FY17-19, and 2.7 FTE in FY20-36.
Funding Required: $350k in FY11, $790k in FY12, $200k/yr in FY13-16, and $100k/yr in FY17-36.</td></tr>
</table>

Table 3. Objective 1.3 – Net-zero facilities.

<table>
<tr><th colspan="2">Objective 1.3: By 2035, develop new and modernize existing facilities to perform at net-zero with respect to energy, water, and waste while providing a high quality of life and adaptable work environment.</th></tr>
<tr><td colspan="2">Description: Change the way we build and renovate buildings to insure that all future infrastructures are sustainable to the greatest extent technologically feasible, cost effective to maintain and operate, and eventually meet Army net-zero waste, energy, and water goals.</td></tr>
<tr><td>Lead Organization: DPW</td><td>Requirements: IR1-4, EN2-1, EN2-2, EN2-3, EO 13514 §2(g)(i), EO 13514 §2(g)(vii), EISA §438, EO 13514 [§2(g)(iv)], EO13514, §2(g)(v), IR3-1, IR3-2, IR3-3, IR3-4, IR5-1, EO 13514 § 2(g)(vi).</td></tr>
<tr><td>Leading Measure(s):
• Percentage of validated restoration and modernization projects compliant with IMCOM energy standards per EN2-1
• Percentage of validated new construction projects that compliant with IMCOM energy standards per EN2-1
• Percentage of all new building construction and renovations certified LEED Silver with measurements and verifications upon completion of construction
• Percentage of Installation designers and energy managers certified as LEED-Accredited Professionals for “whole building” sustainable practice
• Percentage diversion of construction and debris (C&D) waste
• Percentage of square feet meeting Net Zero Ready
• Percentage reduction in Absenteeism
• Number of projects designed/built to meet EISA runoff requirements (within designated SW management areas)</td><td>Lagging Measure(s):
• Reduction in energy use intensity
• Reduction in water use intensity
• Reduction in waste disposal from source reduction, reuse, use of natural/degradable products, and increased recycling
• Workplace accident rate
• Acres of community gardens, reduction in pollutants to streams (sediment and future pollutants)</td></tr>
</table>

<table>
<tr><td colspan="2">Objective 1.3: By 2035, develop new and modernize existing facilities to perform at net-zero with respect to energy, water, and waste while providing a high quality of life and adaptable work environment.</td></tr>
<tr><td>Leading Target(s):
• Design a high-performance building for one OMA-funded building in 2011 – continue to do a different type of OMA-funded construction each year through 2020
• Meet EISA requirements; incorporate Low-Impact Development
• Advanced, centrally monitored, utility metering on 90% of all facilities by 2020 (10% per year)
• All new buildings will be LEED Gold by 2020
• Net Zero energy designed into all buildings for construction or modernization starting in FY2020 as per EO 13514 §2(g)(i)</td><td>Lagging Targets:
• Net Zero Waste by 2035
• Net Zero Water by 2025
• Net Zero Energy by 2020</td></tr>
<tr><td colspan="2">FTEs Required: 2 FTEs starting in 4Q FY11-FY36 for a sustainability engineer (LEED-accredited) and a sustainability coordinator (PAIO)
Funding Required: $315K FY12
• $95K FY13
• $25K/YR starting in FY12 for annual update conference
• Actions will identify additional investments to upgrade infrastructure - these will be integrated into subsequent POM budgets.</td></tr>
</table>

1.4.1 Analysis scenarios

This research investigated the:

- water and resource impacts of energy use and improved efficiencies
- energy and resource impacts of water use and reduction
- energy and water impacts of resource reduction, recycling, and facility demolition.

It is important to plan for the future, and in order to do that, ERDC-CERL looked at the **Baseline** and **Base Case,** or current state of the installation as it exists at this time. ERDC-CERL researchers visited Fort Leonard Wood, conducted site assessments, and talked with numerous people to characterize the current population, building inventory, energy availability and use, water availability and use, waste and deconstruction practices, and plans for population changes, new construction, renovation and facility reduction.

The Base Case is then projected 25 years out. This alternative provides the "status quo" situation for the installation in 25 years. All currently planned improvements, added buildings, and demolished buildings are considered in this alternative. The Base Case is used as a standard to which all other proposed alternatives are compared. The Base Case represents all planned construction and facility reduction planned as of the end of FY12, when this analysis began.

The planned downtown development is not specifically addressed in the alternatives, but the Net Zero Planner was used to assess how changes in high performance building requirements and renewable energy could minimize the energy/water/waste footprint of the new development.

The energy, water, and waste teams used the baseline and Base Case to estimate changes in requirements, population, energy and water use, and waste generation over the 25 year time period. Each team then established alternatives to show how improved practices, sustainable development and high performance buildings could reduce waste generation, energy and water use.

1.4.2 Facility delivery and demolition schedule

The following list shows planned impacts of the Fort Leonard Wood facility-reduction program, in terms of building count and square-footage reductions, from FY14 through FY17:

- FY14: plan to demolish/deconstruct 33 buildings; total reduction of 95,966 SF.
- FY15: plan to demolish/deconstruct 20 buildings; total reduction of 49,700 SF.
- FY16: plan to demolish/deconstruct 36 buildings; total reduction of 204,651 SF.

- FY17: plan to demolish/deconstruct 12 buildings; total reduction of 28,800 SF.

Appendix B captures the master list of specific facilities used by the energy team in the baseline and Base Case analysis.

1.4.3 Installation population assumptions

The installation population data shown in Table 1 were used as the basis for per-capita Net Zero analyses.

Table 1. FLW population data used in analyses.

Year	Reported Post Daytime Population	ASIP* Data	Plus Reserves
FY07	29,337	31,864	482
FY08	29,121	32,744	391
FY09	34,611	34,587	591
FY10	34,876	32,930	531
FY11	35,480	33,215	571
FY12	33,107	32,071	588

* Source: Army Stationing and Installation Plan (ASIP) 2013.

2 Net Zero Energy

This chapter was authored by Michael P. Case, Richard J. Liesen, Matthew M. Swanson, and Benjamin P. Barnes of the ERDC-CERL Energy Branch (CF-E).

2.1 Energy requirements and goals

U.S. federal government agencies are required by law to eliminate fossil fuel use in new and renovated facilities by 2030 and to reduce overall facility energy usage by 30% by 2015 (EISA 2007). New buildings and buildings undergoing major renovations are required to reduce consumption of energy generated by fossil fuels, whether onsite or offsite, as compared with energy consumed by a similar building in FY03 (as measured by Commercial Buildings Energy Consumption Survey [CBECS] or Residential Energy Consumption Survey [RECS] data from the Energy Information Agency). The reduction targets are by 55% in 2010, 80% by 2020, and 100% by 2030. Title 10, Code of Federal Regulations, Part 433 (10 CFR 433, or EPAct 2005) requires that federal facilities be built to achieve at least a 30% energy savings over the 2012 International Energy Code or ASHRAE Standard 90.1-2010, as appropriate, and that energy-efficient designs must be life-cycle cost effective. A U.S. Army policy goal is to achieve nine Net Zero Energy installations by 2020, and 25 by 2030.

Following a series of meetings with installation staff, a list of goals was agreed upon for the Fort Leonard Wood Net Zero Energy study (see Table 2). These goals were intended to guide the analysis and identify the desired end state.

Table 2. FLW Net Zero energy study goals.

Goal	Target	Description
Net Zero Energy	100%	Generate as much renewable energy onsite as the installation uses in a year.
Improve efficiency	30%	Reduce energy use by 30%
Meet critical loads	30 MW	Generate 30 MW of electrical power onsite.
Internal rate of return	7-8%	Make projects attractive to potential investors.

2.2 Baseline condition 2012

For these analyses, the term *Baseline* describes the current state of Fort Leonard Wood as of 2012. This scenario pertains to existing buildings only, with no EEMs (energy-efficiency measures). Note that many data tables provided throughout this chapter, starting immediately below, are presented as direct screen shots from the ERDC-CERL Net Zero Planner (NZP) tool that produced the numbers.

2.2.1 Current energy consumption

Natural gas, electricity, and propane consumptions for FY 2011 are shown in Table 3. Energy Carrier refers to the energy source that the NZP uses, with the description identifying the primary utility.

Table 3. Utility energy consumption.

Energy

Area: ft^2 Electricity: MMBtu Natural Gas: MMBtu Propane: MMBtu Common: MMBtu

Details Graph

Energy Carrier	Description	Year	CM	Area	Cost ($)	Usages	Site Energy (MMBtu)	Source Energy (MMBtu)
Natural Gas	Omega Gas	2011	FY	11,198,000	5,987,847	702,730 MMBtu	702,730	735,758
Electricity	SHOME power	2011	FY	11,147,000	18,529,332	743,150 MMBtu	743,150	2,482,121
Propane	cwC	2013	CY	11,198,000	1,918,237	113,948 MMBtu	113,948	380,586

This results in an electric energy use intensity (EUI) value of 66 kBtu/SF/year, a natural gas intensity value of 63 kBtu/SF/year, and propane of 10 kBtu/SF/year. The total electric and natural gas EUI is 129 kBtu/SF/year, and includes additional components beyond building use such as exterior or street lighting, pumping, water treatment (Table 4).

Table 4. Summary of building energy usage for all of the alternatives.

Study Plan	Facilities	Total Area ft^2	Site Electricity kBtu	Site Electricity Intensity kBtu/ft^2	Site Electricity Reduction (%)	Site Gas kBtu	Site Gas Intensity kBtu/ft^2	Site Gas Reduction (%)	Site Energy Cost ($)
Baseline	495	7,698,669	437,832,160	56.87	0	393,627,200	51.13	0	14,868,177
Base Case	508	9,253,449	530,582,656	57.34	-21.18	449,059,584	48.53	-14.08	17,782,168
Building EEMs High	508	9,253,449	325,483,840	35.17	25.66	225,614,624	24.38	42.68	10,488,019
Building EEMs Realistic	508	9,253,449	417,480,512	45.12	4.65	364,895,520	39.43	7.30	14,089,082
Building EEMs Realistic with AIT Barracks added	508	9,253,449	417,480,512	45.12	4.65	364,895,520	39.43	7.30	14,089,082

The baseline annual EUIs from the building simulation (discussed in the next section) show a combined total of 108 kBtu/SF/year. The building's calculated baseline is the value to which all other results will be compared on a energy-difference basis. This baseline includes a major section of the cantonment area covering the MILCON buildings but excluding the privatized residential housing. The total simulated area was approximately 7.7 million SF for the baseline, and included the buildings on the heating and cooling clusters.

2.2.2 Buildings

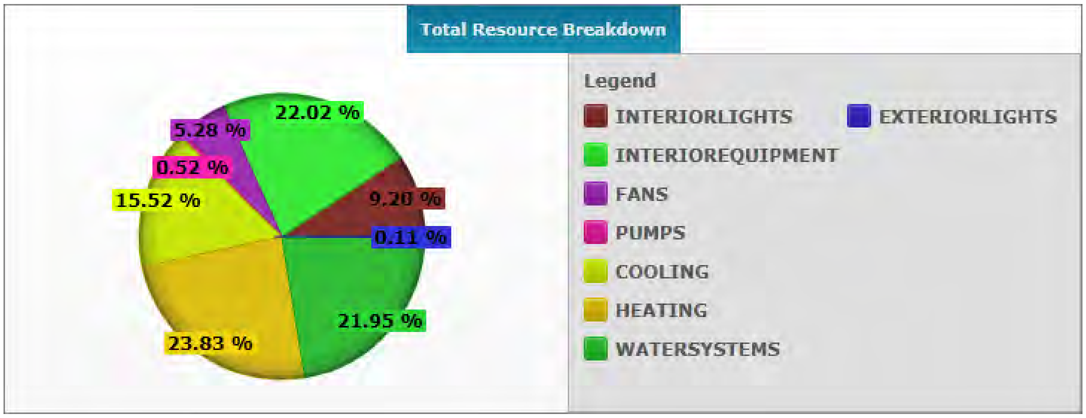
The simulation's total EUIs for the baseline are shown in Table 5 and the figures that follow. For the 495 buildings addressed, it shows the annual building EUI of about 108 kBtu/SF/year. Details for the buildings included in the baseline are given in Appendix B, Facility List.

Table 5. Facility summary for each alternative (emphasis on Baseline).

	Study Plan	Facilities	Total Area (ft^2)	Annual EUI (kBtu/ft^2)
⊞	Base Case	508	9,253,449	106.52
⊞	Baseline	495	7,698,669	107.99
⊞	Building EEMs High	508	9,253,449	57.38
⊞	Building EEMs Realistic	508	9,253,449	84.17
⊞	Building EEMs Realistic with AIT Barracks added	508	9,253,449	84.17
⊞	Building EEMS Realistic with AIT Barracks MTHW	508	9,253,449	84.17

The energy breakdown by percentage is shown in Figure 1. The end uses for the building are shown with energy consumption for building internal equipment loads, domestic hot water, and lighting. Then the energy to condition the building is shown with large amounts for heating, cooling, and ventilation (fan energy). The heating load is in two components, the first is the building heat and the other is the domestic hot water shown as water systems in the charts.

Figure 1. Total energy usage broken down by end use.



The charts show distribution in the monthly electricity and gas intensity distributions to give a comparative analysis (Figure 2 and Figure 3).

Figure 2. Monthly electricity usage by end use.

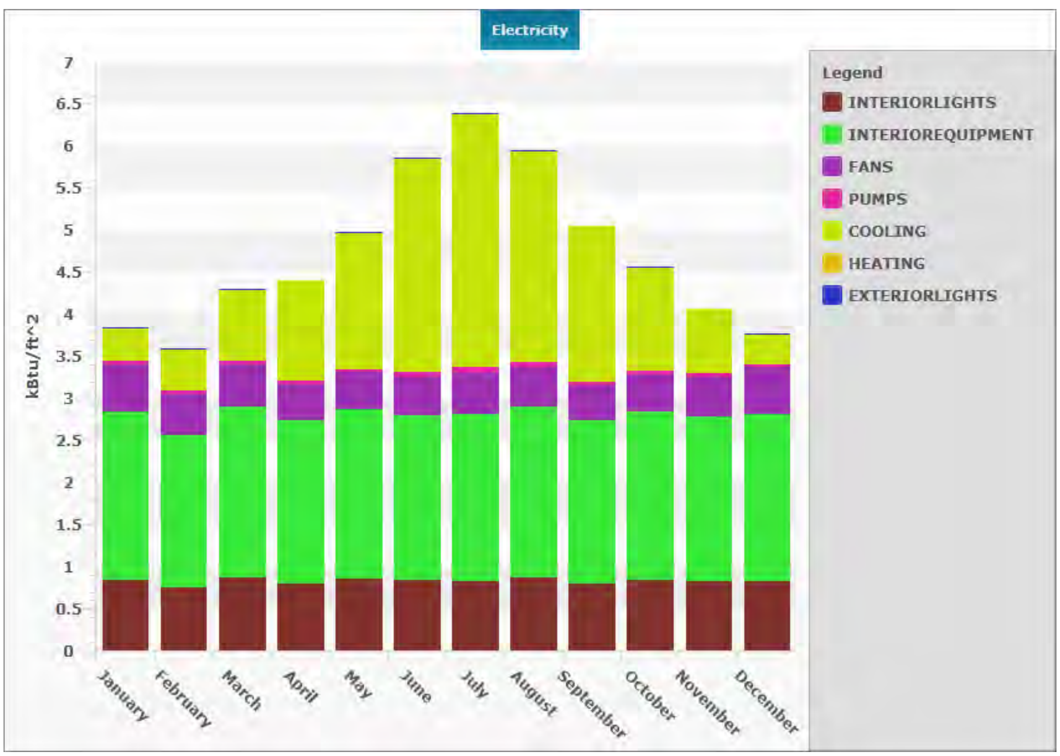
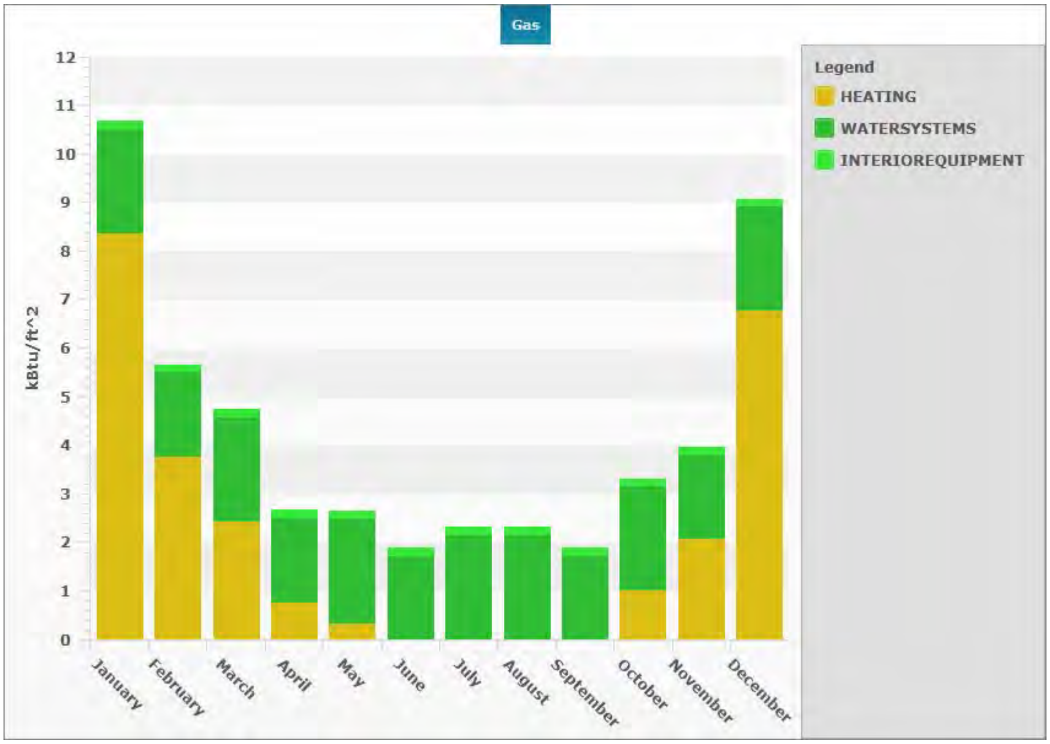


Figure 3. Monthly natural gas usage by end use.



2.2.3 Facility types

Table 6 shows the facility types identified in the Baseline state.

Table 6. Summary of existing building stock (2012).

Facility Group	Facilities	Total Area	Electricity	Electricity Intensity	Electricity Reduction (%)	Gas	Gas Intensity	Gas Reduction (%)	Energy Cost ($)
Admin - existing - pre 1980 wood	7	35,452	1,763,452	49.74	0	726,852	20.50	0	52,646
ARC Existing - Post 1980	1	18,422	669,303	36.33	0	208,896	11.34	0	19,416
ARC Existing - Pre 1980	1	2,304	92,271	40.05	0	36,108	15.67	0	2,738
BdeHQ Existing - 90.1 2007	1	13,264	844,799	63.69	0	42,330	3.19	0	22,641
BdeHQ Existing - Post 1980	6	310,096	19,771,874	63.76	0	2,198,610	7.09	0	540,090
BdeHQ Existing - Pre 1980	12	206,128	14,815,548	71.88	0	3,227,076	15.66	0	418,021
BNHQ Demolish - Pre 1980	3	14,902	675,666	45.34	0	162,282	10.89	0	19,191
BNHQ Demolished - Post 1980	5	33,562	1,452,552	43.28	0	382,806	11.41	0	41,544
BNHQ Existing - 90.1 2007	1	23,045	915,486	39.73	0	166,260	7.21	0	25,551
BNHQ Existing - 90.1 2007	10	135,049	4,731,743	35.04	0	833,442	6.17	0	131,843
BNHQ Existing - Post 1980	52	1,172,061	51,081,880	43.58	0	9,677,556	8.26	0	1,429,059
BNHQ Existing - Pre 1980	71	675,198	37,127,720	54.99	0	12,797,430	18.95	0	1,087,274
CDC Existing - 90.1 2007	1	23,576	849,095	36.02	0	977,670	41.47	0	30,641
CDC Existing - Post 1980	1	24,500	888,481	36.26	0	1,210,434	49.41	0	33,642
COF Demolish - Pre 1980	2	24,268	761,850	31.39	0	366,792	15.11	0	23,189
COF Existing - Post 1980	5	159,359	4,916,315	30.85	0	2,316,318	14.54	0	149,215
COF Existing - Pre 1980	12	154,006	6,632,717	43.07	0	3,496,254	22.70	0	204,439
DFAC Demolish - Pre 1980	2	26,560	6,687,126	251.77	0	2,898,636	109.14	0	200,836
DFAC Existing - 90.1 2007	1	62,234	15,579,530	250.34	0	6,605,214	106.14	0	466,656
DFAC Existing - Post 1980	3	72,225	18,075,172	250.26	0	7,731,600	107.05	0	541,984
DFAC Existing - Pre 1980	11	148,111	37,516,560	253.30	0	17,135,286	115.69	0	1,134,105
Religious Existing - 90.1 2007	1	27,463	1,406,700	51.22	0	1,321,206	48.11	0	48,246

TEMF Demolish - Pre 1980	2	23,347	395,784	16.95	0	809,370	34.67	0	17,264
TEMF Existing - Post 1980	22	400,178	7,925,300	19.80	0	12,834,354	32.07	0	317,269
TEMF Existing - Pre-1980	41	288,885	5,898,124	20.42	0	13,033,356	45.12	0	265,473
TEMF Existing 90.1 2007	7	45,318	735,671	16.23	0	1,256,844	27.73	0	30,003
Trainee Barracks - Demolish - Pre 1980	5	218,444	12,379,528	56.67	0	18,733,626	85.76	0	484,504
Trainee Barracks Existing - Post 1980	6	17,472	1,003,697	57.45	0	1,481,040	84.77	0	38,963
Training Barracks - Existing - 90.1 2007	14	929,960	51,301,736	55.17	0	71,416,424	76.80	0	1,955,402
Training Barracks Existing - Pre 1980	54	1,383,355	80,768,144	58.39	0	126,801,712	91.66	0	3,199,656
Training Barracks Existing - Pre-1980 Renovated	21	455,912	23,427,308	51.39	0	35,531,496	77.93	0	917,557
UEPH Existing	64	162,258	8,653,358	53.33	0	12,424,314	76.57	0	333,017
Warehouse Existing - post 1980 Metal Building	3	8,009	290,159	36.23	0	349,758	43.67	0	10,603
Warehouse - Existing - Pre 1980	43	376,829	16,822,476	44.64	0	23,766,816	63.07	0	644,139
Warehouse Existing - 90.1 2007	4	26,917	975,020	36.22	0	669,018	24.85	0	31,360

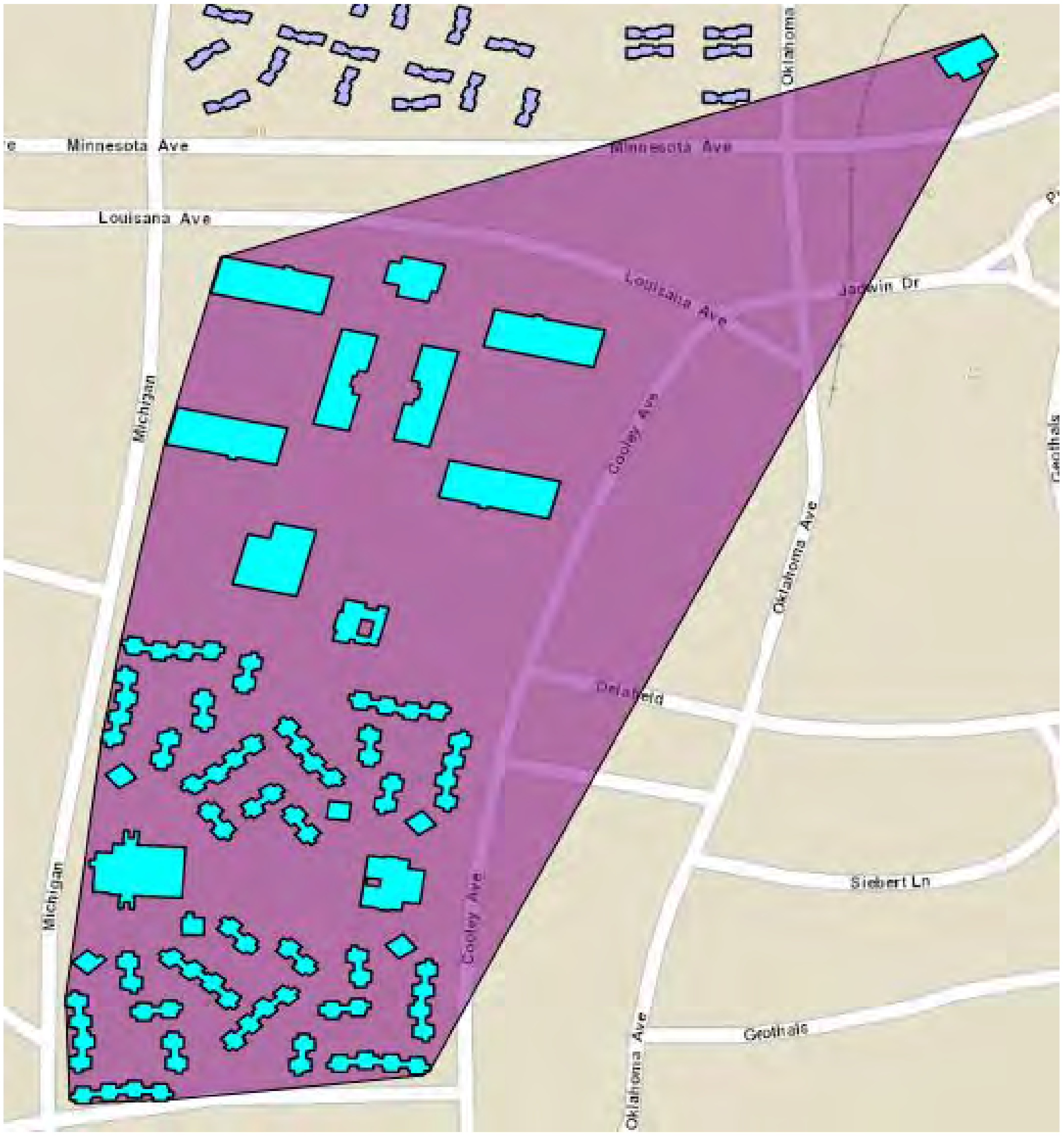
These facility types are modeled and the calculated EUIs are applied to the buildings assigned to these groups. In the baseline alternative, a calibration step adjusts the calculated EUIs to more realistic values based on actual measured EUIs determined at the installation level.

2.2.4 Central plants and distribution

2.2.4.1 Cluster 1 (Specker)

The 46 buildings that make up this cluster (Figure 4) are currently served by the Specker central plant. This central plant contains two boilers and two chillers with their individual capacities shown in Table 7. This study did not include a significant analysis of the electrical distribution equipment on the installation. Consequently, the ACBus1 equipment shown here (and in other clusters) does not represent the current electrical equipment present in or around the central plant and was only used as a placeholder during this analysis. Future work may incorporate an electrical infrastructure analysis and would require an update to this information.

Figure 4. Baseline Specker cluster showing plant (northeastern-most building).



The Specker plant currently distributes through hot and chilled water distribution networks. Hot water leaves the plant at approximately 350 °F and returns between 250–330 °F depending on the thermal load. Chilled water leaves the plant at approximately 42 °F and returns between 47–54 °F depending on the thermal load.

Table 7. Baseline equipment in the Specker plant (individual units).

Equipment	Max Power	Unit	Devices
ACBus1	20,000	kW	1
ExistingBoilers	24.00	MMBtu/hr	2
ExistingElChillers	950.00	ton pwr	2

2.2.4.2 Cluster 2 (South)

The 23 buildings that make up this cluster (blue objects in Figure 5) are currently served by the South central plant. The central plant contains two boilers and two chillers, with their individual capacities shown in Table 8. Currently, the cooling loads for the buildings seem to be overestimated, so the loads cannot be met with the existing equipment. Hypothetical chillers of the same size were added temporarily to serve the simulated cooling load until the actual cooling loads can be revised.

Figure 5. Baseline South cluster.

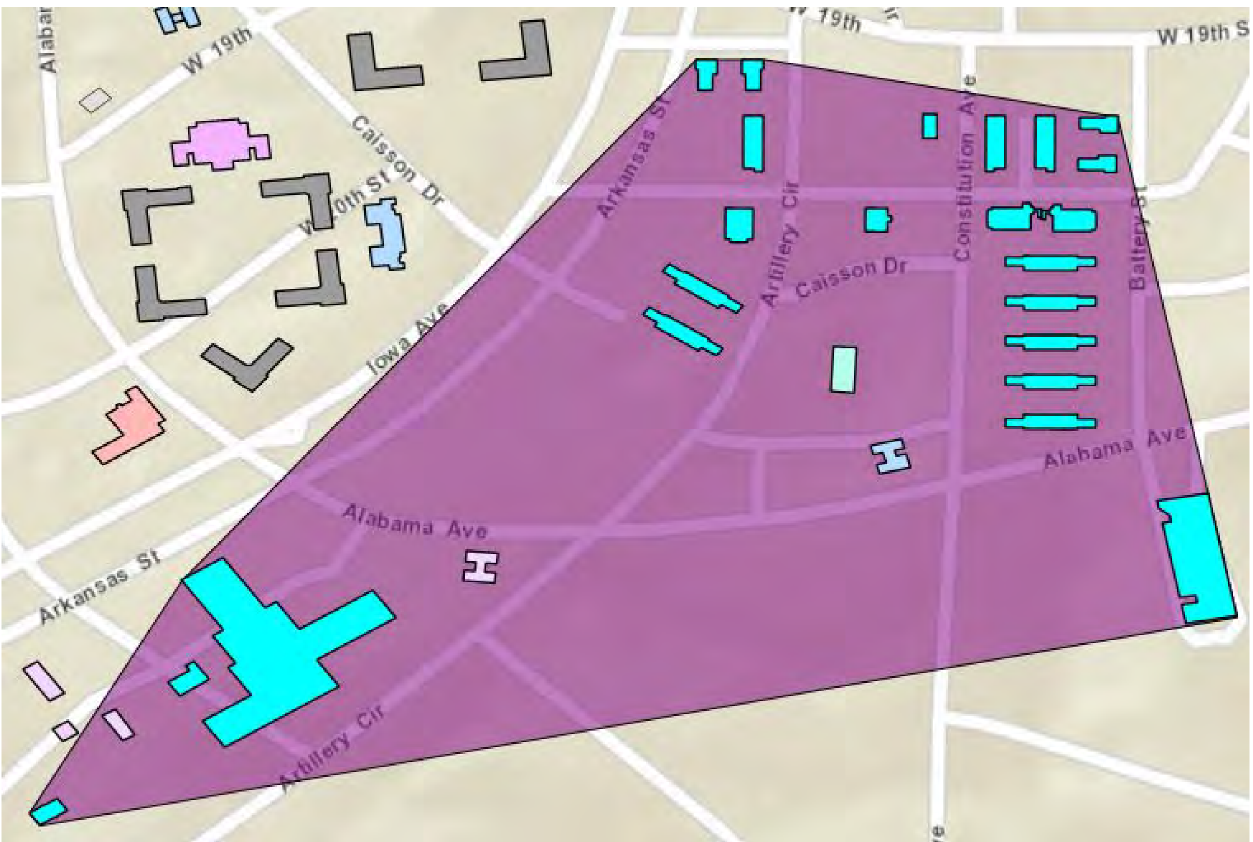


Table 8. Baseline equipment in the South plant (individual units).

Equipment	Max Power	Unit	Devices
ACBus1	20,000	kW	1
ExistingBoilers	33.00	MMBtu/hr	2
ExistingElChillers	350.00	ton pwr	4

The South plant currently distributes through hot and chilled water distribution networks. Hot water leaves the plant at approximately 350 °F and returns at between 250–330 °F depending on the thermal load. Chilled water leaves the plant at approximately 42 °F and returns between 47–54 °F depending on the thermal load.

2.2.4.3 Cluster 3 (West)

The 23 buildings that make up this cluster (blue objects in Figure 6) are currently served by the West central plant. The central plant contains chillers only and the buildings are heated with individual, on-site boilers. The capacities for the two chillers are listed in Table 9. The total heating capacity shown for the distributed boilers is an arbitrarily large number and doesn't correspond to any real capacity. The value listed here is not currently used for any part of the analysis and was made to be large so that it doesn't interfere with other aspects of the optimization. Separate analysis is done to size and cost distributed boilers and chillers for individual buildings. Currently the cooling loads for the buildings seem to be overestimated, so the loads cannot be met with the existing equipment. Hypothetical chillers of the same size were added temporarily to serve the simulated cooling load until the real-world cooling loads can be revised.

Figure 6. Baseline West cluster.

The West plant currently distributes through a chilled water distribution network. Chilled water leaves the plant at approximately 42 °F and returns between 47–54 °F depending on the thermal load.

Table 9. Baseline equipment in the West plant (individual units).

Equipment	Max Power	Unit	Devices
ACBus1	20,000	kW	1
DistBoilersSolution	3,412	MMBtu/hr	1
ExistingElChillers	796.10	ton pwr	3

2.3 Base Case projection

The Base Case represents the status quo condition (i.e., Baseline) projected 25 years into the future, which includes all currently planned improvements, new construction, and demolition currently being considered. The Base Case is the standard scenario to which all other proposed alternatives are compared.

2.3.1 Building and energy summaries

Table 10 shows a list of the buildings and facilities for this alternative.

Table 10. Summary of existing building stock in the Base Case.

Study Plan	Facilities	Total Area ft^2	Site Electricity kBtu	Site Electricity Intensity kBtu/ft^2	Site Electricity Reduction (%)	Site Gas kBtu	Site Gas Intensity kBtu/ft^2	Site Gas Reduction (%)	Site Energy Cos ($)
Baseline	495	7,698,669	437,832,160	56.87	0	393,627,200	51.13	0	14,868,177
Base Case	508	9,253,449	530,582,656	57.34	-21.18	449,059,584	48.53	-14.08	17,782,168

Facility Group	Facilities	Total Area	Electricity	Electricity Intensity	Electricity Reduction (%)	Gas	Gas Intensity	Gas Reduction (%)	Energy Cost ($)
Admin - existing - pre 1980 wood	7	35,452	1,763,452	49.74	0	726,852	20.50	0	52,646
AIT B/COF Planned	2	528,655	26,877,444	50.84	0	21,463,962	40.60	0	889,958
ARC Existing - Post 1980	1	18,422	669,303	36.33	0	208,896	11.34	0	19,416
ARC Existing - Pre 1980	1	2,304	92,271	40.05	0	36,108	15.67	0	2,738
BdeHQ Existing - 90.1 2007	1	13,264	844,799	63.69	0	42,330	3.19	0	22,641
BdeHQ Existing - Post 1980	6	310,096	19,771,874	63.76	0	2,198,610	7.09	0	540,090
BdeHQ Existing - Pre 1980	12	206,128	14,815,548	71.88	0	3,227,076	15.66	0	418,021
BNHQ Existing - 90.1 2007	1	23,045	915,486	39.73	0	166,260	7.21	0	25,551
BNHQ Existing - 90.1 2007	10	135,049	4,731,743	35.04	0	833,442	6.17	0	131,843
BNHQ Existing - Post 1980	52	1,172,061	51,081,880	43.58	0	9,677,556	8.26	0	1,429,059
BNHQ Existing - Pre 1980	71	675,198	37,127,720	54.99	0	12,797,430	18.95	0	1,087,274
BNHQ Planned - 90.1 2007	4	105,284	3,755,792	35.67	0	187,170	1.78	0	100,650
CDC Existing - 90.1 2007	1	23,576	849,095	36.02	0	977,670	41.47	0	30,641
CDC Existing - Post 1980	1	24,500	888,481	36.26	0	1,210,434	49.41	0	33,642
COF Existing - Post 1980	5	159,359	4,916,315	30.85	0	2,316,318	14.54	0	149,215
COF Existing - Pre 1980	12	154,006	6,632,717	43.07	0	3,496,254	22.70	0	204,439
COF Planned - 90.1 2007	1	26,883	657,685	24.46	0	206,142	7.67	0	19,087
DFAC Existing - 90.1 2007	1	62,234	15,579,530	250.34	0	6,605,214	106.14	0	466,656
DFAC Existing - Post 1980	3	72,225	18,075,172	250.26	0	7,731,600	107.05	0	541,984
DFAC Existing - Pre 1980	11	148,111	37,516,560	253.30	0	17,135,286	115.69	0	1,134,105
DFAC Planned - 90.1 2007	3	104,994	26,359,182	251.05	0	11,047,518	105.22	0	788,462
Religious Existing - 90.1 2007	1	27,463	1,406,700	51.22	0	1,321,206	48.11	0	48,246

TEMF Existing - Post 1980	22	400,178	7,925,300	19.80	0	12,834,354	32.07	0	317,269
TEMF Existing - Pre-1980	41	288,885	5,898,124	20.42	0	13,033,356	45.12	0	265,473
TEMF Existing 90.1 2007	7	45,318	735,671	16.23	0	1,256,844	27.73	0	30,003
Trainee Barracks Existing - Post 1980	6	17,472	1,003,697	57.45	0	1,481,040	84.77	0	38,963
Training Barracks - Existing - 90.1 2007	14	929,960	51,301,736	55.17	0	71,416,424	76.80	0	1,955,402
Training Barracks - Planned - 90.1 2007	19	1,106,800	56,271,016	50.84	0	44,937,324	40.60	0	1,863,229
Training Barracks Existing - Pre 1980	54	1,383,355	80,768,144	58.39	0	126,801,712	91.66	0	3,199,656
Training Barracks Existing - Pre-1980 Renovated	21	455,912	23,427,308	51.39	0	35,531,496	77.93	0	917,557
UEPH Existing	64	162,258	8,653,358	53.33	0	12,424,314	76.57	0	333,017
UEPH Planned - ASHRAE 90.1 2007	3	23,247	1,181,905	50.84	0	943,806	40.60	0	39,134
Warehouse Existing - post 1980 Metal Building	3	8,009	290,159	36.23	0	349,758	43.67	0	10,603
Warehouse - Existing - Pre 1980	43	376,829	16,822,476	44.64	0	23,766,816	63.07	0	644,139
Warehouse Existing - 90.1 2007	4	26,917	975,020	36.22	0	669,018	24.85	0	31,360

The Base Case energy and EUI figures are shown in Table 11 and Figure 7 through Figure 9. If the new buildings are built to current specifications, the overall annual EUI will drop by approximately 1.5 kBtu/SF/year, which is not much. The large amount of existing facilities keeps the average approximately the same. With an increase in area of approximately 1.55 million SF, the electric energy use increases approximately 20% and the natural gas consumption increases by about 15%.

Table 11. Facility summary for each alternative (emphasis on the Base Case).

Study Plan	Facilities	Total Area (ft^2)	Annual EUI (kBtu/ft^2)
Base Case	508	9,253,449	106.52
Baseline	495	7,698,669	107.99
Building EEMs High	508	9,253,449	57.38
Building EEMs Realistic	508	9,253,449	84.17
Building EEMs Realistic with AIT Barracks added	508	9,253,449	84.17
Building EEMS Realistic with AIT Barracks MTHW	508	9,253,449	84.17

Figure 7. Energy consumption by end use.

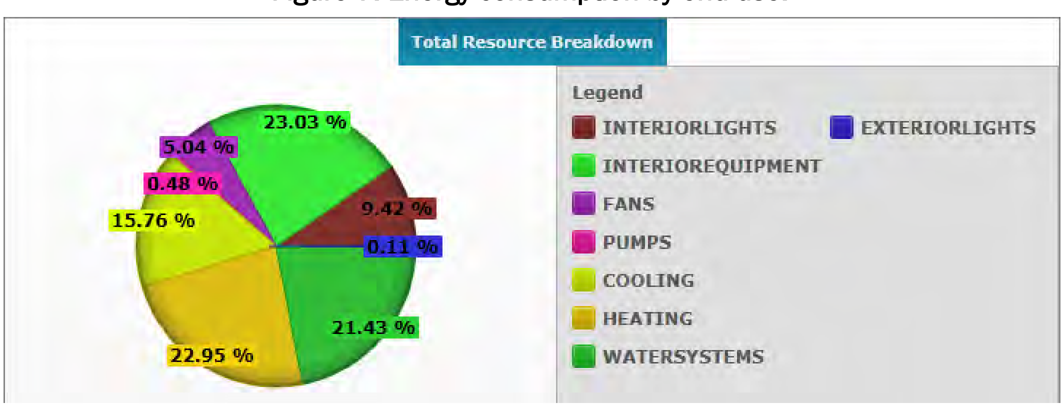


Figure 8. Monthly electricity consumption by end use.

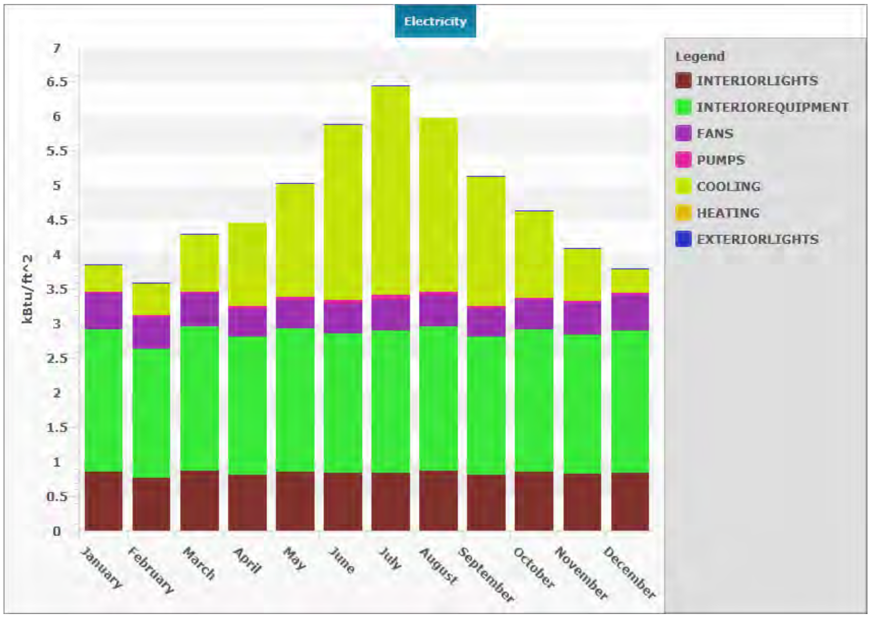
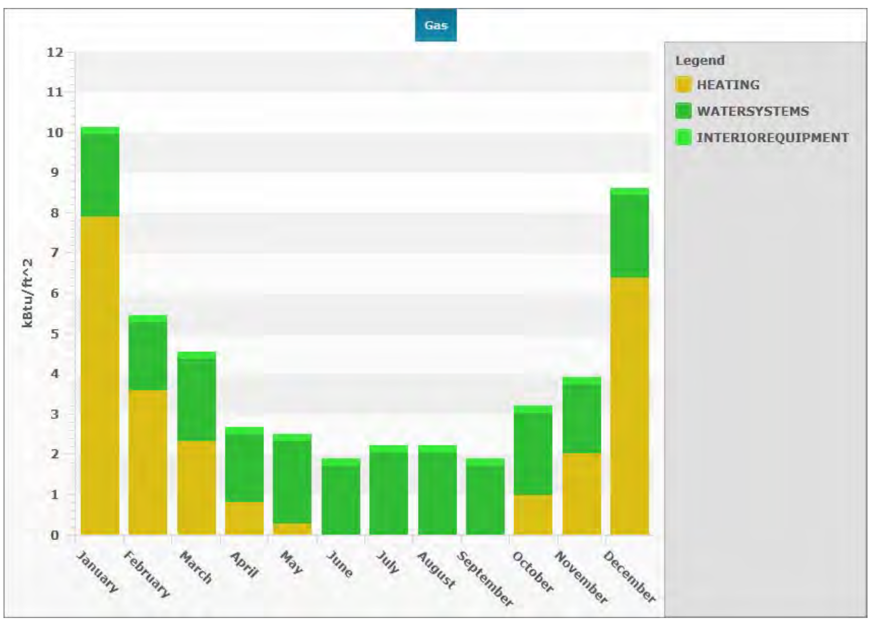


Figure 9. Monthly natural gas consumption by end use.



2.3.2 Central plants and distribution

2.3.2.1 Cluster 1 (Specker)

The 46 buildings that make up this cluster will continue to be served by the Specker central plant. No changes are planned for the number of buildings served by the central plant or the central plant equipment in the Base Case, as shown in Table 12.

Table 12. Base Case equipment capacities in the Specker plant per individual unit.

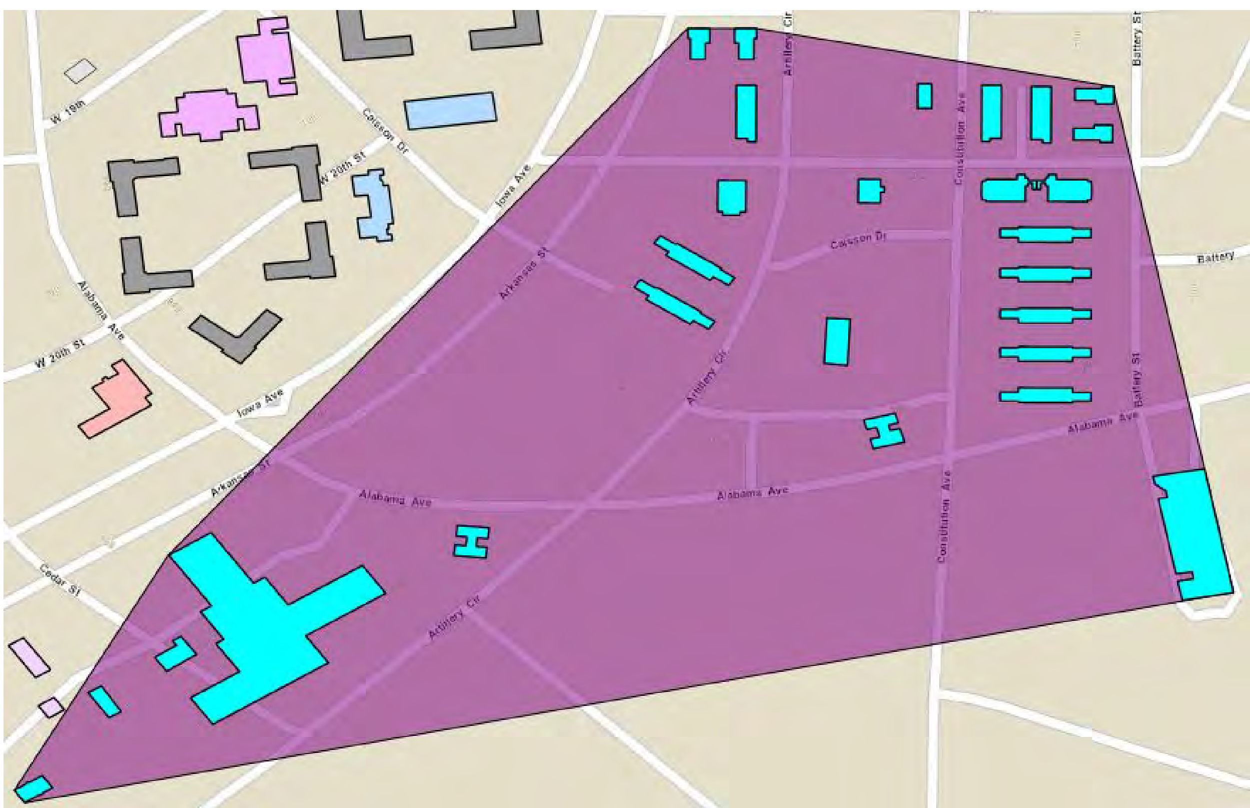
Equipment	Max Power	Unit	Devices
ACBus1	20,000	kW	1
ExistingBoilers	24.00	MMBtu/hr	2
ExistingElChillers	950.00	ton pwr	2

The Specker plant distributes through hot and chilled water distribution networks. Hot water leaves the plant at approximately 350 °F and returns at between 250-330 °F depending on the thermal load. Chilled water leaves the plant at approximately 42 °F and returns between 47-54 °F depending on the thermal load.

2.3.2.2 Cluster 2 (South)

The 27 buildings that make up this cluster are planned to continue to be served by the South central plant. This cluster is scheduled to lose 4 buildings from its current state (see the baseline data in previous section). No changes are planned for the central plant equipment in the Base Case (Figure 10).

Figure 10. Base Case South cluster.



The South plant has both hot and chilled water distribution networks (Table 13). Hot water leaves the plant at approximately 350 °F and returns at between 250–330 °F depending on the thermal load. Chilled water leaves the plant at approximately 42 °F and returns between 47-54 °F depending on the thermal load.

Table 13. Base Case equipment capacities in the South plant per individual unit.

Equipment	Max Power	Unit	Devices
ACBus1	20,000	kW	1
ExistingBoilers	33.00	MMBtu/hr	2
ExistingElChillers	350.00	ton pwr	4

2.3.2.3 Cluster 3 (West)

The 16 buildings that make up the West cluster (Figure 11) are planned to continue to be served by the West central plant. This cluster is scheduled to lose 7 buildings from its current state (see Baseline data). No changes are planned for the central plant equipment in the Base Case, as shown in Table 14.

Figure 11. Base Case West cluster.

Table 14. Estimated Base Case equipment capacities per individual unit.

Equipment	Max Power	Unit	Devices
ACBus1	20,000	kW	1
DistBoilersSolution	3,412	MMBtu/hr	1
ExistingElChillers	796.10	ton pwr	2

The West plant distributes through a chilled water distribution network. Chilled water leaves the plant at approximately 42 °F and returns between 47–54 °F depending on the thermal load.

2.4 Overview of alternative scenarios

Four alternative scenarios were modeled for comparison to the Base Case scenario:

- Alternative 1–building EEM high option
- Alternative 2–building EEM realistic option
- Alternative 3–Alternative 2 with Advance Individual Training (AIT) barracks included in Specker cluster
- Alternative 4–Alternative 3 plus dropping distribution temperature for South and Specker clusters.

The EEM packages evaluated for some of the facilities are shown in Table 15 through Table 20. The listed facilities are a sample of the actual modeled facility groups, and were selected by either conditioned-space or energy-use criteria.

Table 15. Building EEMs simulated for the planned or new AIT B/COFs.

AIT B/COF Planned

Charts | Detail View

Package	Electric Usage (kBtu)	Electric Cost ($)	Gas Usage (kBtu)	Gas Cost ($)	Energy Reduction (%)
Default	26,877,444	708,987	21,463,962	180,971	0
Envelope Package	26,815,642	707,357	20,115,420	169,601	2.92
Infiltration Package	27,058,448	713,762	19,840,020	167,279	2.98
Lighting Package	23,179,368	611,437	20,039,430	168,960	10.60
HVAC Package	20,972,872	553,233	18,010,548	151,854	19.36
Energy Recovery Package	21,043,040	555,084	10,754,574	90,676	34.22
Radiant-ERV Package	19,189,876	506,200	10,650,942	89,802	38.27
Chilled Beam-ERV Package	21,256,024	560,702	10,765,896	90,771	33.76
ERV and IDEC Package	20,543,768	541,914	10,754,574	90,676	35.26
Indirect Evap Cooling Package	20,476,698	540,145	18,010,548	151,854	20.38
Radiant-ERV-IDEC Package	18,741,728	494,379	10,650,942	89,802	39.20
DHW Package	19,169,526	505,664	8,572,284	72,276	42.61
Drainwater HR Package	19,169,526	505,664	8,572,284	72,276	42.61
Daylighting Package	19,108,956	504,066	8,588,910	72,416	42.70
Equipment Package	14,968,362	394,843	8,920,920	75,216	50.58

Table 16. EEMs simulated for BdeHQ – post 1980.

BdeHQ Existing - Post 1980

Charts Detail View

Package	Electric Usage (kBtu)	Electric Cost ($)	Gas Usage (kBtu)	Gas Cost ($)	Energy Reduction (%)
Baseline	19,771,874	521,553	2,198,610	18,537	0
Lighting Package	17,005,678	448,584	2,661,996	22,444	10.48
Equipment Package	14,934,445	393,948	3,252,882	27,426	17.22
Infiltration Package	15,087,378	397,983	978,282	8,248	26.88
HVAC Package	14,131,881	372,778	769,386	6,487	32.18
CoolRoof Package	13,943,938	367,820	838,644	7,071	32.72
Daylighting Package	13,811,104	364,316	850,374	7,170	33.27

Table 17. EEMs simulated for BNHQ – post 1980.

BNHQ Existing - Post 1980

Charts Detail View

Package	Electric Usage (kBtu)	Electric Cost ($)	Gas Usage (kBtu)	Gas Cost ($)	Energy Reduction (%)
Baseline	51,081,880	1,347,464	9,677,556	81,595	0
Lighting Package	49,609,972	1,308,637	9,965,400	84,022	1.95
Equipment Package	35,493,864	936,275	13,217,466	111,441	19.83
Infiltration Package	35,844,284	945,519	5,257,692	44,330	32.35
HVAC Package	30,026,280	792,048	4,093,158	34,511	43.85
CoolRoof Package	29,130,012	768,406	4,386,918	36,988	44.84
Daylighting Package	28,615,704	754,840	4,442,406	37,456	45.59

Table 18. EEMs simulated for Training Barracks – pre 1980.

Training Barracks Existing - Pre 1980

Charts Detail View

Package	Electric Usage (kBtu)	Electric Cost ($)	Gas Usage (kBtu)	Gas Cost ($)	Energy Reduction (%)
Baseline	80,768,144	2,130,543	126,801,712	1,069,112	0
Infiltration Package	79,996,080	2,110,177	113,227,752	954,665	6.91
Lighting Package	73,490,736	1,938,576	115,779,584	976,181	8.82
HVAC Package	57,677,004	1,521,433	98,008,736	826,348	25.00
DHW Package	57,633,224	1,520,278	55,336,936	466,566	45.57
Drainwater HR Package	57,633,224	1,520,278	55,336,936	466,566	45.57
Daylighting Package	57,282,824	1,511,036	55,417,720	467,247	45.70
Equipment Package	45,504,312	1,200,336	60,321,576	508,594	49.02
CoolRoof Package	45,100,940	1,189,696	61,532,216	518,801	48.63

Table 19. Building EEMs simulated for UEPH Existing.

UEPH Existing

Charts | Detail View

Package	Electric Usage (kBtu)	Electric Cost ($)	Gas Usage (kBtu)	Gas Cost ($)	Energy Reduction (%)
Baseline	8,653,358	228,263	12,424,314	104,754	0
Infiltration Package	8,824,761	232,784	11,624,328	98,009	2.98
Lighting Package	7,836,619	206,718	11,761,620	99,167	7.02
HVAC Package	7,140,457	188,355	10,153,488	85,608	17.95
DHW Package	7,056,444	186,138	5,064,300	42,699	42.49
Drainwater HR Package	7,056,444	186,138	5,064,300	42,699	42.49
Daylighting Package	7,015,174	185,050	5,066,544	42,718	42.68
Equipment Package	5,288,942	139,514	5,342,148	45,042	49.56
CoolRoof Package	5,143,027	135,665	5,389,068	45,437	50.03

Table 20. Building EEMs simulated for building type Warehouse – Existing – pre 1980.

Warehouse - Existing - Pre 1980

Charts | Detail View

Package	Electric Usage (kBtu)	Electric Cost ($)	Gas Usage (kBtu)	Gas Cost ($)	Energy Reduction (%)
Baseline	16,822,476	443,752	23,766,816	200,387	0
Envelope Package	15,233,591	401,839	21,704,478	182,999	9.00
Infiltration Package	9,160,526	241,641	545,802	4,602	76.09
Lighting Package	5,745,119	151,548	1,111,698	9,373	83.11
HVAC Package	5,346,790	141,040	1,301,214	10,971	83.62
Solar Preheat Package	5,346,790	141,040	1,301,214	10,971	83.62

The EEM options are more aggressive for new construction than for existing buildings. From this sampling of the facilities and EEM options, the retrofit EEMs were applied to existing buildings and new EEMs were applied to new construction.

2.5 Alternative 1

Alternative 1 represents significant improvements to the buildings on the installation, representing highest-quality EEMs that will be available. This section describes those improvements and their energy implications.

2.5.1 Buildings

Table 21 lists the buildings and facilities for this alternative future scenario. The EEMs specified and evaluated here is a sampling from the larger facility groups based either on conditioned space area or energy usage. An example of the parameters for a facility is shown in Table 21 and then results for several facility types are shown in Table 22, Table 23, Figure 12, Figure 13, and Figure 14.

Table 21. Summary of existing building stock in Alternative 1.

Study Plan	Facilities	Total Area ft^2	Site Electricity kBtu	Site Electricity Intensity kBtu/ft^2	Site Electricity Reduction (%)	Site Gas kBtu	Site Gas Intensity kBtu/ft^2	Site Gas Reduction (%)	Site Energy Cos ($)
Baseline	495	7,698,669	437,832,160	56.87	0	393,627,200	51.13	0	14,868,177
Base Case	508	9,253,449	530,582,656	57.34	-21.18	449,059,584	48.53	-14.08	17,782,168
Building EEMs High	508	9,253,449	325,483,840	35.17	25.66	225,614,624	24.38	42.68	10,488,019

Facility Group	Facilities	Total Area	Electricity	Electricity Intensity	Electricity Reduction (%)	Gas	Gas Intensity	Gas Reduction (%)	Energy Cost ($)
Admin - existing - pre 1980 wood	7	35,452	998,548	28.17	43.38	326,910	9.22	55.02	29,097
AIT B/COF Planned	2	528,655	14,968,362	28.31	0	8,920,920	16.87	0	470,059
ARC Existing - Post 1980	1	18,422	398,585	21.64	40.45	171,462	9.31	17.92	11,960
ARC Existing - Pre 1980	1	2,304	51,618	22.40	44.06	27,132	11.78	24.86	1,590
BdeHQ Existing - 90.1 2007	1	13,264	604,546	45.58	28.44	24,276	1.83	42.65	16,152
BdeHQ Existing - Post 1980	6	310,096	13,811,104	44.54	30.15	850,374	2.74	61.32	371,486
BdeHQ Existing - Pre 1980	12	206,128	9,255,372	44.90	37.53	1,448,094	7.03	55.13	256,352
BNHQ Existing - 90.1 2007	1	23,045	557,632	24.20	39.09	63,750	2.77	61.66	15,247
BNHQ Existing - 90.1 2007	10	135,049	3,243,657	24.02	31.45	295,494	2.19	64.55	88,054
BNHQ Existing - Post 1980	52	1,172,061	28,615,704	24.41	43.98	4,442,406	3.79	54.10	792,295
BNHQ Existing - Pre 1980	71	675,198	19,017,790	28.17	48.78	6,226,284	9.22	51.35	554,157
BNHQ Planned - 90.1 2007	4	105,284	2,706,011	25.70	0	117,504	1.12	0	72,371
CDC Existing - 90.1 2007	1	23,576	612,284	25.97	27.89	838,134	35.55	14.27	23,218
CDC Existing - Post 1980	1	24,500	642,598	26.23	27.67	901,986	36.82	25.48	24,556
COF Existing - Post 1980	5	159,359	3,269,519	20.52	33.50	1,760,622	11.05	23.99	101,089
COF Existing - Pre 1980	12	154,006	3,969,153	25.77	40.16	2,357,934	15.31	32.56	124,581
COF Planned - 90.1 2007	1	26,883	419,008	15.59	0	137,292	5.11	0	12,210
DFAC Existing - 90.1 2007	1	62,234	12,778,014	205.32	17.98	6,259,128	100.57	5.24	389,838
DFAC Existing - Post 1980	3	72,225	14,839,854	205.47	17.90	7,314,930	101.28	5.39	453,128
DFAC Existing - Pre 1980	11	148,111	30,909,400	208.69	17.61	15,747,780	106.32	8.10	948,119
DFAC Planned - 90.1 2007	3	104,994	19,895,134	189.49	0	10,510,692	100.11	0	613,424
Religious Existing - 90.1 2007	1	27,463	865,707	31.52	38.46	955,128	34.78	27.71	30,889
TEMF Existing - Post 1980	22	400,178	5,560,268	13.89	29.84	9,650,016	24.11	24.81	228,034
TEMF Existing - Pre-1980	41	288,885	4,384,046	15.18	25.67	9,154,500	31.69	29.76	192,830
TEMF Existing 90.1 2007	7	45,318	620,667	13.70	15.63	991,950	21.89	21.08	24,736
Trainee Barracks Existing - Post 1980	6	17,472	558,983	31.99	44.31	678,708	38.85	54.17	20,468
Training Barracks - Existing - 90.1 2007	14	929,960	29,314,804	31.52	42.86	32,342,670	34.78	54.71	1,045,974
Training Barracks - Planned - 90.1 2007	19	1,106,800	31,503,560	28.46	0	18,505,860	16.72	0	987,047
Training Barracks Existing - Pre 1980	54	1,383,355	45,100,940	32.60	44.16	61,532,216	44.48	51.47	1,708,496
Training Barracks Existing - Pre-1980 Renovated	21	455,912	14,371,555	31.52	38.65	15,856,002	34.78	55.37	512,788
UEPH Existing	64	162,258	5,143,027	31.70	40.57	5,389,068	33.21	56.62	181,103
UEPH Planned - ASHRAE 90.1 2007	3	23,247	661,694	28.46	0	388,722	16.72	0	20,732
Warehouse Existing - post 1980 Metal Building	3	8,009	111,885	13.97	61.44	28,764	3.59	91.78	3,194
Warehouse - Existing - Pre 1980	43	376,829	5,346,790	14.19	68.22	1,301,214	3.45	94.53	152,011
Warehouse Existing - 90.1 2007	4	26,917	376,029	13.97	61.43	96,696	3.59	85.55	10,734

Table 22 shows a sample of EEM enhancements that are simulated for the buildings. The green selected package is actually used for the realistic (most affordable) package of EEMs for an alternative where the advanced selection is package 14. The high EEM options selected for all facilities apply to deep retrofit of existing buildings and the new buildings designed to high performance standards.

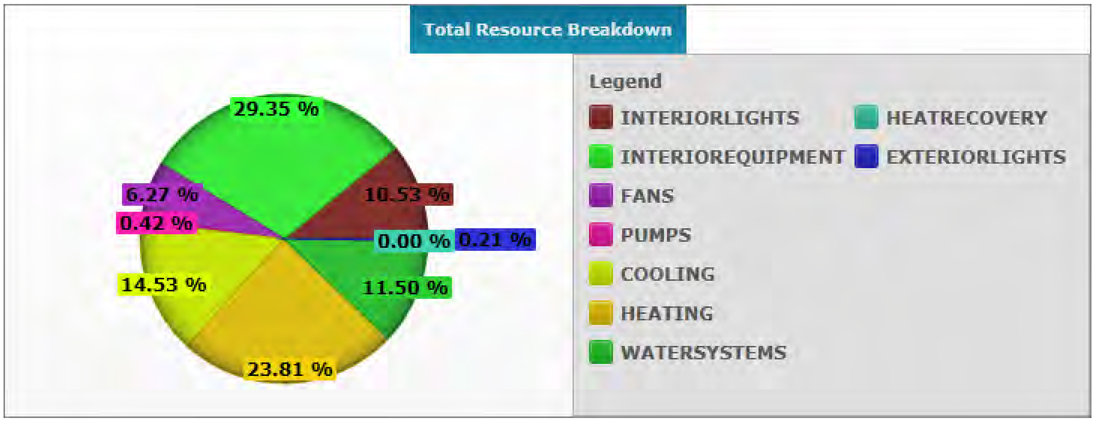
Table 22. Sample EEM enhancement for a building.

Parameters	Default or Baseline	Envelope Package #1	Infiltration Package #2	Lighting Package #3	HVAC Package #4	Energy Recovery Package #5	Radiant - ERV Package #6	Chilled Beam - ERV Package #7	ERV - IDEC Package #8	IDEC Package #9	Radiant - ERV - IDEC Package #10	DHW Package #11	Drainwater Recovery Package #12	Daylighting #13	Equipment Reduction Package #14
air_leakage	0.4	0.4	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
boiler_eff	0.8	0.8	0.8	0.8	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
boiler_type	NONCONDENSING	NONCONDENSING	NONCONDENSING	NONCONDENSING	CONDENSING	CONDENSING	CONDENSING	CONDENSING	CONDENSING	CONDENSING	CONDENSING	CONDENSING	CONDENSING	CONDENSING	CONDENSING
chiller_cond_hr	false	false	false	false	false	false	false	false	false	false	false	false	false	false	false
chiller_cop	2.87	2.87	2.87	2.87	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45
cooling_coil_type	CHILLEDWATER	CHILLEDWATER	CHILLEDWATER	CHILLEDWATER	CHILLEDWATER	CHILLEDWATER	CHILLEDWATER	CHILLEDWATER	CHILLEDWATER	CHILLEDWATER	CHILLEDWATER	CHILLEDWATER	CHILLEDWATER	CHILLEDWATER	CHILLEDWATER
cooling_setpoint	75	75	75	75	75	75	78	75	75	75	78	78	78	78	78
daylighting_controls	false	false	false	false	false	false	false	false	false	false	false	false	false	true	true
demand_control_vent	false	false	false	false	false	false	false	false	false	false	false	false	false	false	false
dhw_residence	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	1.5
drainwater_hr	false	false	false	false	false	false	false	false	false	false	false	false	true	true	true
equipment_density_commons	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.33
equipment_density_residence	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	0.835
exfil_ratio	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
fan_eff_fcu	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
fan_eff_return	0.65	0.65	0.65	0.65	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
fan_eff_supply	0.65	0.65	0.65	0.65	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
heating_setpoint	70	70	70	70	70	70	68	70	70	70	68	68	68	68	68
heating_source	BOILER	BOILER	BOILER	BOILER	BOILER	BOILER	BOILER	BOILER	BOILER	BOILER	BOILER	BOILER	BOILER	BOILER	BOILER
lamp_type	T12	T12	T12	T8	T8	T8	T8	T8	T8	T8	T8	T8	T8	T8	T8
lighting_controls	NONE	NONE	NONE	ADVANCED	ADVANCED	ADVANCED	ADVANCED	ADVANCED	ADVANCED	ADVANCED	ADVANCED	ADVANCED	ADVANCED	ADVANCED	ADVANCED
lighting_density_corridor	0.5	0.5	0.5	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
lighting_density_residence	1.0	1.0	1.0	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
lighting_density_stairwell	0.6	0.6	0.6	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
oa_desiccant_hx	false	false	false	false	false	false	false	false	false	false	false	false	false	false	false
oa_dwelling	90	90	65	65	65	65	65	65	65	65	65	65	65	65	65
oa_energy_recovery	false	false	false	false	false	true	true	true	true	false	true	true	true	true	true
oa_er_latent_eff	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
oa_er_sensible_eff	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
oa_indirect_evap	false	false	false	false	false	false	false	false	true	true	true	false	false	false	false
oa_solar_preheat	false	false	false	false	false	false	false	false	false	false	false	false	false	false	false
pump_eff_cw	0.73	0.73	0.73	0.73	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
pump_eff_hw	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
roof_assembly_type	Insulation Above Deck	Insulation Above Deck	Insulation Above Deck	Insulation Above Deck	Insulation Above Deck	Insulation Above Deck	Insulation Above Deck	Insulation Above Deck	Insulation Above Deck	Insulation Above Deck	Insulation Above Deck	Insulation Above Deck	Insulation Above Deck	Insulation Above Deck	Insulation Above Deck
roof_cavity_insulation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
roof_continuous_insulation	20	45	45	45	45	45	45	45	45	45	45	45	45	45	45
roof_emittance	0.85	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
roof_reflectance	0.2	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
sat_reset_control	NONE	NONE	NONE	NONE	OUTDOORTEMP	OUTDOORTEMP	OUTDOORTEMP	OUTDOORTEMP	OUTDOORTEMP	OUTDOORTEMP	OUTDOORTEMP	OUTDOORTEMP	OUTDOORTEMP	OUTDOORTEMP	OUTDOORTEMP
side_daylighting	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	LIGHTSHELF	LIGHTSHELF
slab_insulation	0	15	15	15	15	15	15	15	15	15	15	15	15	15	15
supply_hw_setpoint_type	Constant	Constant	Constant	Constant	Reset	Reset	Reset	Reset	Reset	Reset	Reset	Reset	Reset	Reset	Reset
top_daylighting	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	TUBULAR	TUBULAR
wall_assembly_type	Mass Wall	Steel Framing at 16 in. on center	Steel Framing at 16 in. on center	Steel Framing at 16 in. on center	Steel Framing at 16 in. on center	Steel Framing at 16 in. on center	Steel Framing at 16 in. on center	Steel Framing at 16 in. on center	Steel Framing at 16 in. on center	Steel Framing at 16 in. on center	Steel Framing at 16 in. on center	Steel Framing at 16 in. on center	Steel Framing at 16 in. on center	Steel Framing at 16 in. on center	Steel Framing at 16 in. on center
wall_cavity_insulation	0	19	19	19	19	19	19	19	19	19	19	19	19	19	19
wall_continuous_insulation	9.5	25	25	25	25	25	25	25	25	25	25	25	25	25	25
water_heater_eff	0.8	0.8	0.8	0.8	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
window_shgc	0.40	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
window_u	0.55	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
zone_hvac_residence	FANCOILAIR	FANCOILAIR	FANCOILAIR	FANCOILAIR	FANCOILAIR	FANCOILAIR	RADIANTAIR	CHILLEDBEAMRADIATOR	FANCOILAIR	FANCOILAIR	RADIANTAIR	RADIANTAIR	RADIANTAIR	RADIANTAIR	RADIANTAIR

Table 23. Facility summary for each alternative (emphasis on high EEMs).

Study Plan	Facilities	Total Area (ft^2)	Annual EUI (kBtu/ft^2)
Base Case	508	9,253,449	106.52
Baseline	495	7,698,669	107.99
Building EEMs High	508	9,253,449	57.38
Building EEMs Realistic	508	9,253,449	84.17
Building EEMs Realistic with AIT Barracks added	508	9,253,449	84.17
Building EEMS Realistic with AIT Barracks MTHW	508	9,253,449	84.17

Figure 12. Energy consumption by end use.



The charts show distribution in the monthly electricity and gas intensity distributions to give a comparative analysis (Figure 13 and Figure 14).

Figure 13. Electricity consumption by end use.

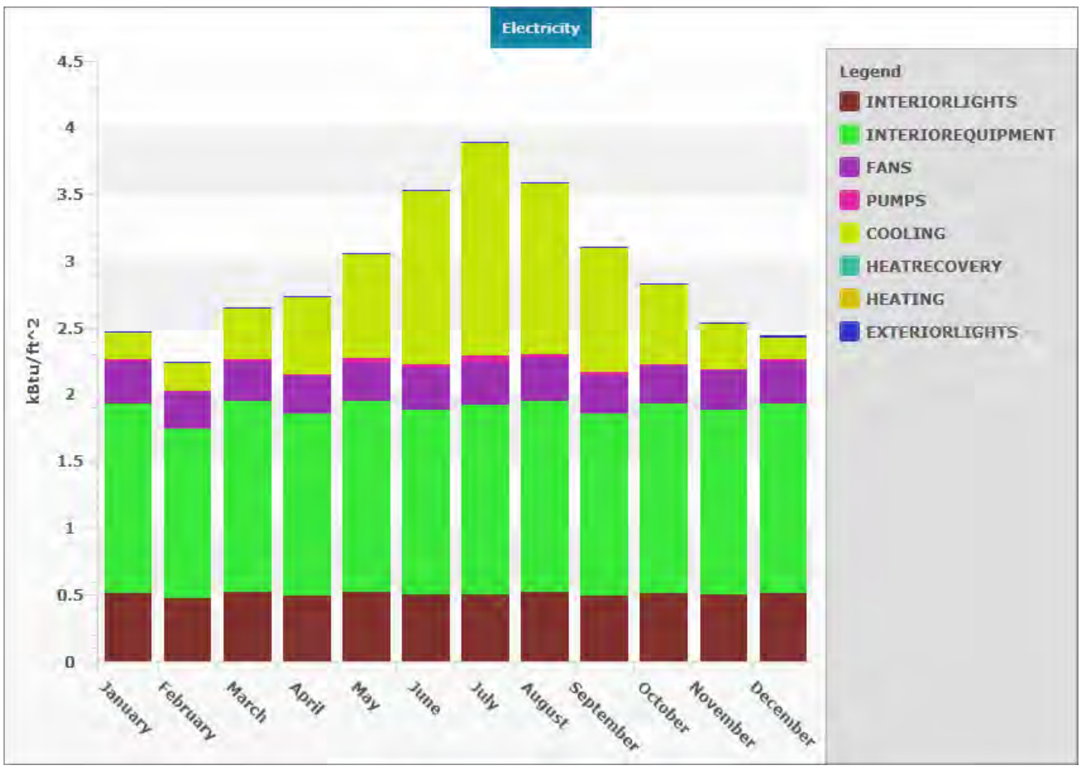
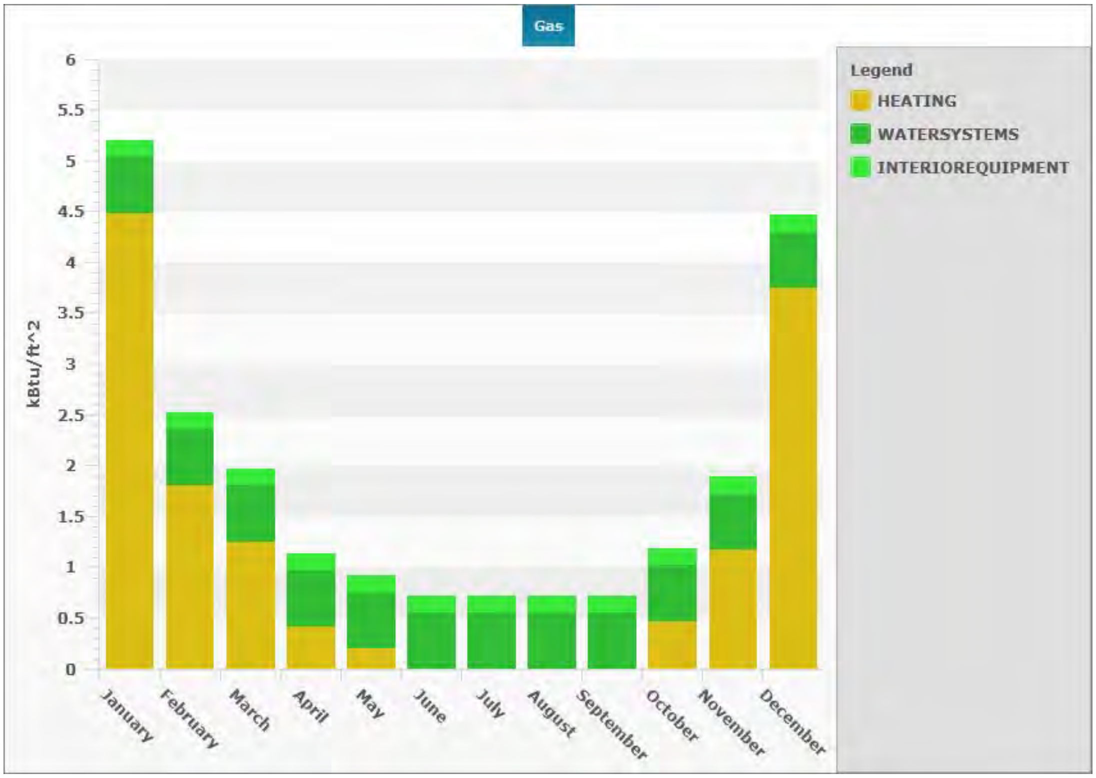


Figure 14. Natural gas consumption by end use.



With the results from the high EEM option, the reduction in annual EUI is a little less than half and provides an overall reduction in electric and natural gas consumption, which reduces the overall utility usage for the installation. With this option, every retrofit and new construction project needs to be constructed to high performance standards.

2.5.2 Central plants and distribution

2.5.2.1 Cluster 1 (Specker)

The 46 buildings that make up this cluster will continue to be served by the Specker central plant. The suggested central plant equipment, as determined by the Net Zero Planner is shown in Table 24. A few observations should be made about these results.

Table 24. Equipment suggested for Alternative 1 in the Specker plant.

Equipment	Max Power	Unit	Devices
ACBus1	20,000	kW	1
Air_Elec_Chill_3	189.90	ton pwr	1
ExistingBoilers	23.70	MMBtu/hr	2
ExistingElChillers	949.60	ton pwr	2

This alternative adds a relatively small air-cooled chiller to meet the *n plus one* constraint that requires the maximum load to be met while missing any single piece of equipment. The optimization chose a cheaper, lower-efficiency chiller (COP ~3) to meet this constraint since it is only needed when one of the larger units is down. Efficient base load operation would still be handled by the two existing water-cooled chillers.

The Specker plant distributes through hot and chilled water pipe networks. Hot water leaves the plant at approximately 350 °F and returns at between 250-330 °F depending on the thermal load. Chilled water leaves the plant at approximately 42 °F and returns between 47-54 °F depending on the thermal load.

2.5.2.2 Cluster 2 (South)

The 27 buildings that make up this cluster will continue to be served by the South central plant. A few observations should be made about these results shown in Table 25.

This alternative adds additional air-cooled chillers. The additional air-cooled chillers were added to meet the capacity and *n plus one* constraint requirements. The *n plus one* constraint requires the maximum load to be met while missing any single piece of equipment. The optimization chose a cheaper, lower efficiency chiller (COP ~3) to meet this constraint since it is only needed when one of the larger units is down. Efficient baseload operation would still be performed by the two existing water-cooled chillers.

The South plant distributes through hot and cold water distribution networks. Hot water leaves the plant at approximately 350 °F and returns at between 250-330 °F depending on the thermal load. Chilled water leaves the plant at approximately 42 °F and returns between 47-54 °F depending on the thermal load.

Table 25. Equipment suggested for Alternative 1 in the South plant. Capacities shown for each individual unit.

Equipment	Max Power	Unit	Devices	
ACBus1	20,000	kW	1	
Air_Elec_Chill_4	300.00	ton pwr	2	
ExistingBoilers	32.60	MMBtu/hr	2	
ExistingElChillers	349.70	ton pwr	2	

2.5.2.3 Cluster 3 (West)

The 16 buildings that make up this cluster (see Base Case West for a map of this cluster) will continue to be served by the West central plant. The results of the analysis are provided in Table 26.

This alternative adds an additional air-cooled chiller. The additional air cooled chiller was added to meet the capacity and *n plus one* constraint requirements. The *n plus one* constraint requires the maximum load to be met while missing any single piece of equipment. The optimization chose a cheaper, lower efficiency chiller (COP ~3) to meet this constraint since it is only needed when one of the larger units is down. Efficient baseload operation would still be performed by the two existing water-cooled chillers.

Chilled water leaves the plant at approximately 42 °F and returns between 47-54 °F depending on the thermal load.

Table 26. Equipment suggested for Alternative 1 in the West plant. Capacities shown for each individual unit.

Equipment	Max Power	Unit	Devices
ACBus1	20,000	kW	1
Air_Elec_Chill_5	499.80	ton pwr	1
DistBoilersSolution	3,412	MMBtu/hr	1
ExistingElChillers	796.10	ton pwr	2

2.6 Alternative 2

This alternative represents realistic improvements as compared with the high-EEM options under Alternative 1. These improvements, and their energy implications, are described in this section. Table 27 shows a summary of the buildings for Alternative 2.

2.6.1 Buildings

Table 27. Summary of existing building stock in Alternative 2.

Study Plan	Facilities	Total Area ft^2	Site Electricity kBtu	Site Electricity Intensity kBtu/ft^2	Site Electricity Reduction (%)	Site Gas kBtu	Site Gas Intensity kBtu/ft^2	Site Gas Reduction (%)	Site Energy Cos ($)
Baseline	495	7,698,669	437,832,160	56.87	0	393,627,200	51.13	0	14,868,177
Base Case	508	9,253,449	530,582,656	57.34	-21.18	449,059,584	48.53	-14.08	17,782,168
Building EEMs High	508	9,253,449	325,483,840	35.17	25.66	225,614,624	24.38	42.68	10,488,019
Building EEMs Realistic	508	9,253,449	417,480,512	45.12	4.65	364,895,520	39.43	7.30	14,089,082

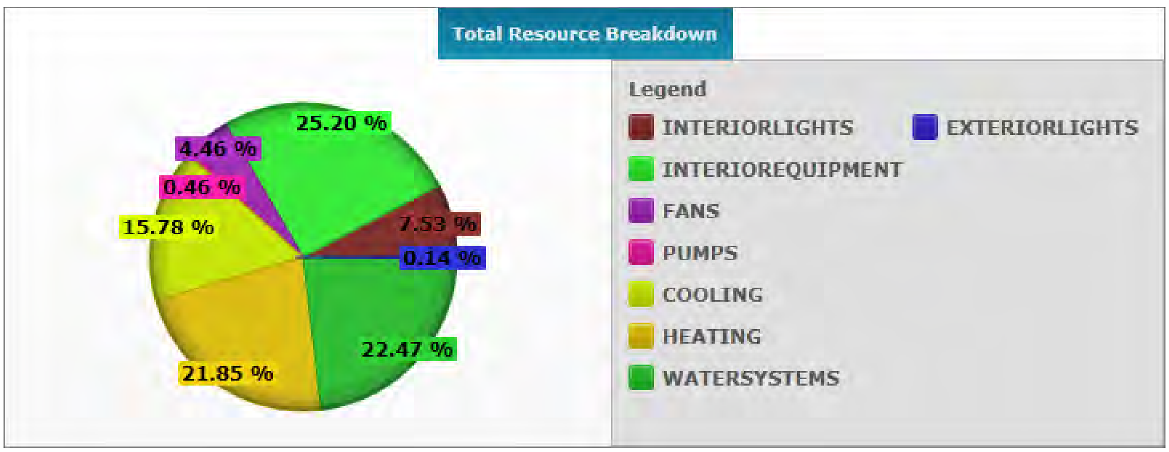
Facility Group	Facilities	Total Area	Electricity	Electricity Intensity	Electricity Reduction (%)	Gas	Gas Intensity	Gas Reduction (%)	Energy Cost ($)
Admin - existing - pre 1980 wood	7	35,452	1,398,979	39.46	20.67	844,764	23.83	-16.22	44,025
AIT B/COF Planned	2	528,655	20,972,872	39.67	0	18,010,548	34.07	0	705,087
ARC Existing - Post 1980	1	18,422	425,112	23.08	36.48	202,980	11.02	2.83	12,925
ARC Existing - Pre 1980	1	2,304	55,262	23.99	40.11	42,636	18.51	-18.08	1,817
BdeHQ Existing - 90.1 2007	1	13,264	618,579	46.64	26.78	22,032	1.66	47.95	16,503
BdeHQ Existing - Post 1980	6	310,096	15,087,378	48.65	23.69	978,282	3.15	55.50	406,231
BdeHQ Existing - Pre 1980	12	206,128	11,459,583	55.59	22.65	4,210,560	20.43	-30.48	337,788
BNHQ Existing - 90.1 2007	1	23,045	580,666	25.20	36.57	58,956	2.56	64.54	15,814
BNHQ Existing - 90.1 2007	10	135,049	3,378,773	25.02	28.59	268,362	1.99	67.80	91,390
BNHQ Existing - Post 1980	52	1,172,061	35,844,284	30.58	29.83	5,257,692	4.49	45.67	989,848
BNHQ Existing - Pre 1980	71	675,198	26,644,120	39.46	28.24	16,066,734	23.80	-25.55	838,297
BNHQ Planned - 90.1 2007	4	105,284	2,566,950	24.38	0	77,826	0.74	0	68,368
CDC Existing - 90.1 2007	1	23,576	624,061	26.47	26.50	833,238	35.34	14.77	23,487
CDC Existing - Post 1980	1	24,500	653,260	26.66	26.47	899,028	36.70	25.73	24,812
COF Existing - Post 1980	5	159,359	4,202,231	26.37	14.52	1,749,402	10.98	24.47	125,598
COF Existing - Pre 1980	12	154,006	5,299,768	34.41	20.10	3,916,188	25.43	-12.01	172,819
COF Planned - 90.1 2007	1	26,883	430,295	16.01	0	126,990	4.72	0	12,421
DFAC Existing - 90.1 2007	1	62,234	12,872,755	206.84	17.37	6,237,912	100.23	5.56	392,158
DFAC Existing - Post 1980	3	72,225	15,591,700	215.88	13.74	7,942,944	109.97	-2.73	478,256
DFAC Existing - Pre 1980	11	148,111	32,366,316	218.53	13.73	17,820,726	120.32	-4.00	1,004,028
DFAC Planned - 90.1 2007	3	104,994	20,190,504	192.30	0	10,454,592	99.57	0	620,742
Religious Existing - 90.1 2007	1	27,463	1,256,056	45.74	10.71	1,132,098	41.22	14.31	42,678
TEMF Existing - Post 1980	22	400,178	5,602,186	14.00	29.31	11,458,476	28.63	10.72	244,388
TEMF Existing - Pre-1980	41	288,885	4,589,103	15.89	22.19	13,689,930	47.39	-5.04	236,479
TEMF Existing 90.1 2007	7	45,318	620,667	13.70	15.63	991,950	21.89	21.08	24,736
Trainee Barracks Existing - Post 1980	6	17,472	726,878	41.60	27.58	1,144,542	65.51	22.72	28,824
Training Barracks - Existing - 90.1 2007	14	929,960	42,394,996	45.59	17.36	58,528,212	62.94	18.05	1,611,790
Training Barracks - Planned - 90.1 2007	19	1,106,800	43,909,120	39.67	0	37,707,056	34.07	0	1,476,179
Training Barracks Existing - Pre 1980	54	1,383,355	73,490,736	53.12	9.01	115,779,584	83.69	8.69	2,914,757
Training Barracks Existing - Pre-1980 Renovated	21	455,912	18,627,028	40.86	20.49	14,655,258	32.14	58.75	614,917
UEPH Existing	64	162,258	7,836,619	48.30	9.44	11,761,620	72.49	5.33	305,885
UEPH Planned - ASHRAE 90.1 2007	3	23,247	922,259	39.67	0	792,030	34.07	0	31,006
Warehouse Existing - post 1980 Metal Building	3	8,009	120,262	15.02	58.55	23,970	2.99	93.15	3,374
Warehouse - Existing - Pre 1980	43	376,829	5,745,119	15.25	65.85	1,111,698	2.95	95.32	160,921
Warehouse Existing - 90.1 2007	4	26,917	376,029	13.97	61.43	96,696	3.59	85.55	10,734

The EEMs chosen for this alternative are not as aggressive as those of Alternative 1. The existing buildings are retrofit with usual energy performance enhancements and not pushed to high performance deep retrofit. The new buildings are selected to meet Standard 189 or a little better.

Table 28. Facility summary for each alternative (emphasis on the "Building EEMs Realistic" alternative).

	Study Plan	Facilities	Total Area (ft^2)	Annual EUI (kBtu/ft^2)
⊞	Base Case	508	9,253,449	106.52
⊞	Baseline	495	7,698,669	107.99
⊞	Building EEMs High	508	9,253,449	57.38
⊞	Building EEMs Realistic	508	9,253,449	84.17
⊞	Building EEMs Realistic with AIT Barracks added	508	9,253,449	84.17
⊞	Building EEMS Realistic with AIT Barracks MTHW	508	9,253,449	84.17

Figure 15. Energy usage by end use.



The charts show distribution in the monthly electricity and gas intensity distributions to give a comparative analysis (Figure 16 and Figure 17).

Figure 16. Electricity usage by end use.

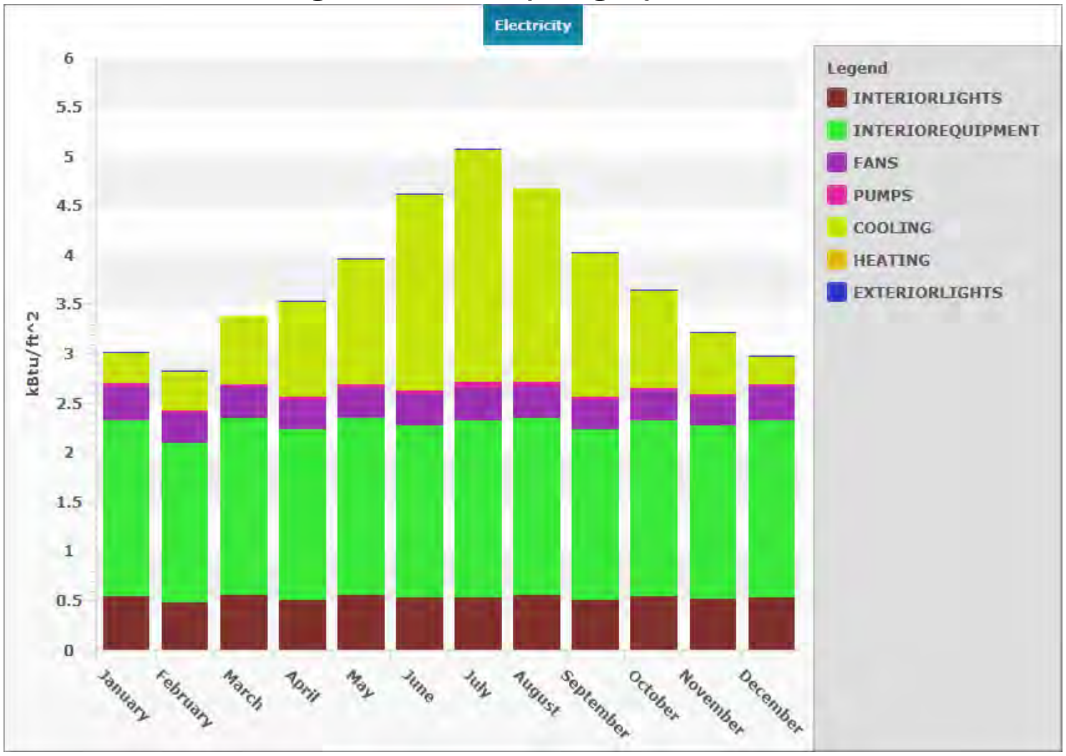
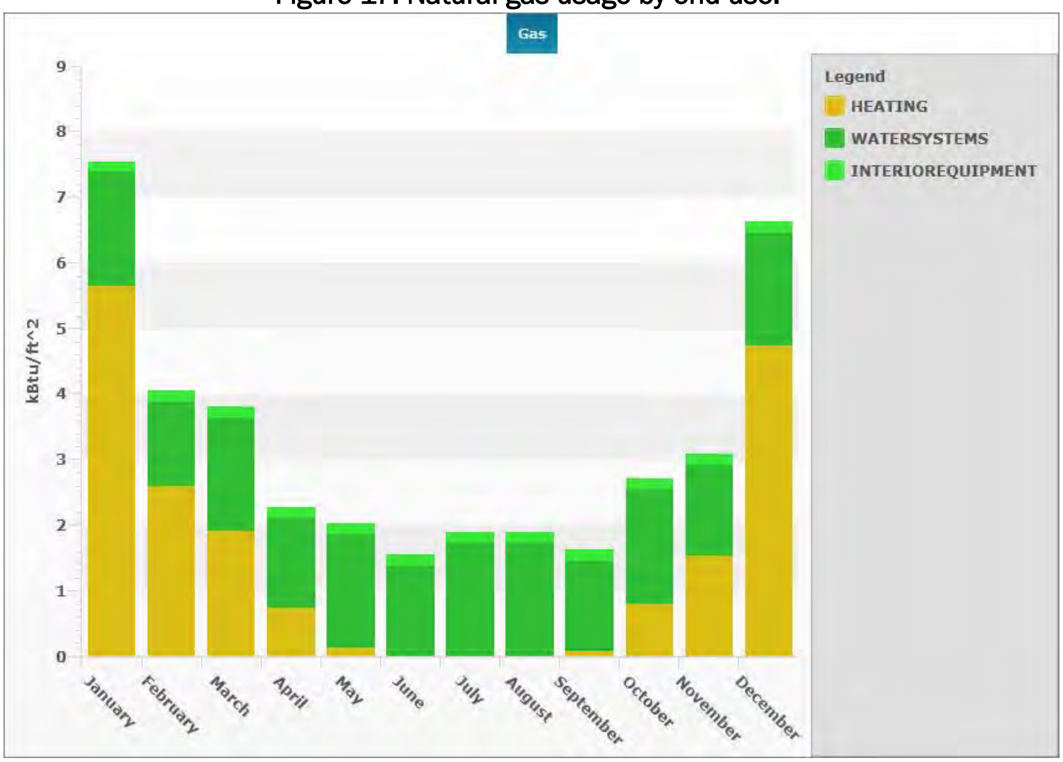


Figure 17. Natural gas usage by end use.



This alternative gives about a 4.5% reduction in electric and about a 7% reduction in natural gas and allows the approximately 1.55 million SF increase in conditioned area with no increase in installation energy from building usage.

2.6.2 Central plants and distribution

2.6.2.1 Cluster 1 (Specker)

The 46 buildings that make up this cluster (see Baseline Specker for a map of this cluster) will continue to be served by the Specker central plant. The suggested central plant equipment (as determined by the Net Zero Planner) is shown in Table 29.

This alternative adds an additional air cooled chiller and natural gas boiler capacity. The additional air cooled chiller and boiler capacity were added to meet the capacity and *n plus one* constraint requirements. The *n plus one* constraint requires the maximum load to be met while missing any single piece of equipment. The optimization chose a cheaper, lower efficiency chiller (COP ~3) to meet this constraint since it is only needed when one of the larger units is down. Efficient base load operation would still be performed by the two existing water cooled chillers. The additional boilers should be viewed as total additional boiler capacity, not a recommendation toward the specific number and sizes given in the table.

The Specker plant distributes through hot and chilled water distribution networks. Hot water leaves the plant at approximately 350 °F and returns at between 250-330 °F depending on the thermal load. Chilled water leaves the plant at approximately 42 °F and returns between 47-54 °F depending on the thermal load.

Table 29. Equipment suggested for Alternative 2 in the Specker plant. Capacities shown for each individual unit.

Equipment	Max Power	Unit	Devices
ACBus1	20,000	kW	1
Air_Elec_Chill_4	300.00	ton pwr	1
Boil0	0.30	MMBtu/hr	1
Boil1	3.40	MMBtu/hr	4
ExistingBoilers	23.70	MMBtu/hr	2
ExistingElChillers	949.60	ton pwr	2

2.6.2.2 Cluster 2 (South)

The 27 buildings that make up this cluster (see Base Case South for a map of this cluster) will continue to be served by the South central plant. The results of the analysis are provided in Table 30.

This alternative adds an additional air cooled chiller and natural gas boiler capacity. The additional air cooled chiller and boiler capacity were added to meet the capacity and *n plus one* constraint requirements. The *n plus one* constraint requires the maximum load to be met while missing any single piece of equipment. The optimization chose a cheaper, lower efficiency chiller (COP ~3) to meet this constraint since it is only needed when one of the larger units is down. Efficient base load operation would still be performed by the two existing water cooled chillers. The additional boilers should be viewed as total additional boiler capacity, not a recommendation toward the specific number and sizes given in the table.

The South plant distributes through hot and chilled water distribution networks. Hot water leaves the plant at approximately 350 °F and returns at between 250-330 °F depending on the thermal load. Chilled water leaves the plant at approximately 42 °F and returns between 47-54 °F depending on the thermal load.

Table 30. Equipment suggested for Alternative 2 in the South plant. Capacities shown for each individual unit.

Equipment	Max Power	Unit	Devices
ACBus1	20,000	kW	1
Air_Elec_Chill_2	100.10	ton pwr	1
Air_Elec_Chill_4	300.00	ton pwr	2
Boil1	3.40	MMBtu/hr	1
ExistingBoilers	32.60	MMBtu/hr	2
ExistingElChillers	349.70	ton pwr	2

2.6.2.3 Cluster 3 (West)

The 16 buildings that make up this cluster (see Base Case West for a map of this cluster) will continue to be served by the West central plant. The results of the analysis are provided in Table 31.

This alternative adds an additional air cooled chiller. The additional air cooled chiller was added to meet the capacity and *n plus one* constraint requirements. The *n plus one* constraint requires the maximum load to be met while missing any single piece of equipment. The optimization chose a cheaper, lower efficiency chiller (COP ~3) to meet this constraint since it is only needed when one of the larger units is down. Efficient baseload operation would still be performed by the two existing water cooled chillers.

Chilled water leaves the plant at approximately 42 °F and returns between 47–54 °F depending on the thermal load.

Table 31. Equipment suggested for Alternative 2 in the West plant. Capacities shown for each individual unit.

Equipment	Max Power	Unit	Devices
ACBus1	20,000	kW	1
Air_Elec_Chill_4	300.00	ton pwr	2
DistBoilersSolution	3,412	MMBtu/hr	1
ExistingElChillers	796.10	ton pwr	2

2.7 Alternative 3

This alternative is exactly like alternative 2, but with the addition of the AIT Barracks to the Specker cluster. This addition changed the heating and cooling equipment requirements for the Specker plant, but ultimately results in significantly less energy use and initial equipment costs with HVAC and central plant equipment downsizing. The energy and cost comparison for the alternatives is presented in the conclusions and recommendations section.

2.7.1 Buildings

Table 32. Summary of existing building stock in Alternative 3.

Study Plan	Facilities	Total Area ft^2	Site Electricity kBtu	Site Electricity Intensity kBtu/ft^2	Site Electricity Reduction (%)	Site Gas kBtu	Site Gas Intensity kBtu/ft^2	Site Gas Reduction (%)	Site Energy Cos ($)
Baseline	495	7,698,669	437,832,160	56.87	0	393,627,200	51.13	0	14,868,177
Base Case	508	9,253,449	530,582,656	57.34	-21.18	449,059,584	48.53	-14.08	17,782,168
Building EEMs High	508	9,253,449	325,483,840	35.17	25.66	225,614,624	24.38	42.68	10,488,019
Building EEMs Realistic	508	9,253,449	417,480,512	45.12	4.65	364,895,520	39.43	7.30	14,089,082
Building EEMs Realistic with AIT Barracks added	508	9,253,449	417,480,512	45.12	4.65	364,895,520	39.43	7.30	14,089,082

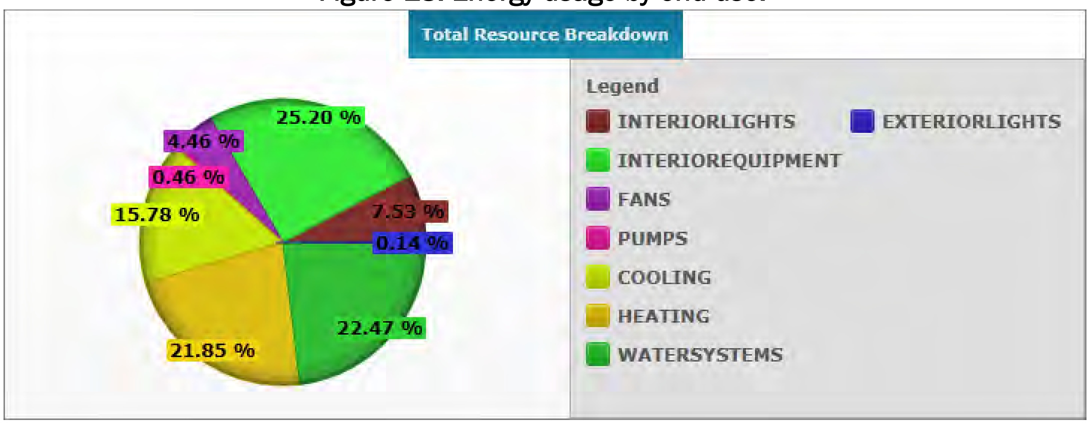
Facility Group	Facilities	Total Area	Electricity	Electricity Intensity	Electricity Reduction (%)	Gas	Gas Intensity	Gas Reduction (%)	Energy Cost ($)
Admin - existing - pre 1980 wood	7	35,452	1,398,979	39.46	20.67	844,764	23.83	-16.22	44,025
AIT B/COF Planned	2	528,655	20,972,872	39.67	0	18,010,548	34.07	0	705,087
ARC Existing - Post 1980	1	18,422	425,112	23.08	36.48	202,980	11.02	2.83	12,925
ARC Existing - Pre 1980	1	2,304	55,262	23.99	40.11	42,636	18.51	-18.08	1,817
BdeHQ Existing - 90.1 2007	1	13,264	618,579	46.64	26.78	22,032	1.66	47.95	16,503
BdeHQ Existing - Post 1980	6	310,096	15,087,378	48.65	23.69	978,282	3.15	55.50	406,231
BdeHQ Existing - Pre 1980	12	206,128	11,459,583	55.59	22.65	4,210,560	20.43	-30.48	337,788
BNHQ Existing - 90.1 2007	1	23,045	580,666	25.20	36.57	58,956	2.56	64.54	15,814
BNHQ Existing - 90.1 2007	10	135,049	3,378,773	25.02	28.59	268,362	1.99	67.80	91,390
BNHQ Existing - Post 1980	52	1,172,061	35,844,284	30.58	29.83	5,257,692	4.49	45.67	989,848
BNHQ Existing - Pre 1980	71	675,198	26,644,120	39.46	28.24	16,066,734	23.80	-25.55	838,297
BNHQ Planned - 90.1 2007	4	105,284	2,566,950	24.38	0	77,826	0.74	0	68,368
CDC Existing - 90.1 2007	1	23,576	624,061	26.47	26.50	833,238	35.34	14.77	23,487
CDC Existing - Post 1980	1	24,500	653,260	26.66	26.47	899,028	36.70	25.73	24,812
COF Existing - Post 1980	5	159,359	4,202,231	26.37	14.52	1,749,402	10.98	24.47	125,598
COF Existing - Pre 1980	12	154,006	5,299,768	34.41	20.10	3,916,188	25.43	-12.01	172,819
COF Planned - 90.1 2007	1	26,883	430,295	16.01	0	126,990	4.72	0	12,421
DFAC Existing - 90.1 2007	1	62,234	12,872,755	206.84	17.37	6,237,912	100.23	5.56	392,158
DFAC Existing - Post 1980	3	72,225	15,591,700	215.88	13.74	7,942,944	109.97	-2.73	478,256
DFAC Existing - Pre 1980	11	148,111	32,366,316	218.53	13.73	17,820,726	120.32	-4.00	1,004,028
DFAC Planned - 90.1 2007	3	104,994	20,190,504	192.30	0	10,454,592	99.57	0	620,742
Religious Existing - 90.1 2007	1	27,463	1,256,056	45.74	10.71	1,132,098	41.22	14.31	42,678
TEMF Existing - Post 1980	22	400,178	5,602,186	14.00	29.31	11,458,476	28.63	10.72	244,388
TEMF Existing - Pre-1980	41	288,885	4,589,103	15.89	22.19	13,689,930	47.39	-5.04	236,479
TEMF Existing 90.1 2007	7	45,318	620,667	13.70	15.63	991,950	21.89	21.08	24,736
Trainee Barracks Existing - Post 1980	6	17,472	726,878	41.60	27.58	1,144,542	65.51	22.72	28,824
Training Barracks - Existing - 90.1 2007	14	929,960	42,394,996	45.59	17.36	58,528,212	62.94	18.05	1,611,790
Training Barracks - Planned - 90.1 2007	19	1,106,800	43,909,120	39.67	0	37,707,056	34.07	0	1,476,179
Training Barracks Existing - Pre 1980	54	1,383,355	73,490,736	53.12	9.01	115,779,584	83.69	8.69	2,914,757
Training Barracks Existing - Pre-1980 Renovated	21	455,912	18,627,028	40.86	20.49	14,655,258	32.14	58.75	614,917
UEPH Existing	64	162,258	7,836,619	48.30	9.44	11,761,620	72.49	5.33	305,885
UEPH Planned - ASHRAE 90.1 2007	3	23,247	922,259	39.67	0	792,030	34.07	0	31,006
Warehouse Existing - post 1980 Metal Building	3	8,009	120,262	15.02	58.55	23,970	2.99	93.15	3,374
Warehouse - Existing - Pre 1980	43	376,829	5,745,119	15.25	65.85	1,111,698	2.95	95.32	160,921
Warehouse Existing - 90.1 2007	4	26,917	376,029	13.97	61.43	96,696	3.59	85.55	10,734

The building energy is the same as the previous alternative.

Table 33: Facility summary for each alternative (emphasis on the “Building EEMs Realistic with AIT barracks” alternative).

Study Plan	Facilities	Total Area (ft^2)	Annual EUI (kBtu/ft^2)
Base Case	508	9,253,449	106.52
Baseline	495	7,698,669	107.99
Building EEMs High	508	9,253,449	57.38
Building EEMs Realistic	508	9,253,449	84.17
Building EEMs Realistic with AIT Barracks added	508	9,253,449	84.17
Building EEMS Realistic with AIT Barracks MTHW	508	9,253,449	84.17

Figure 18: Energy usage by end use.



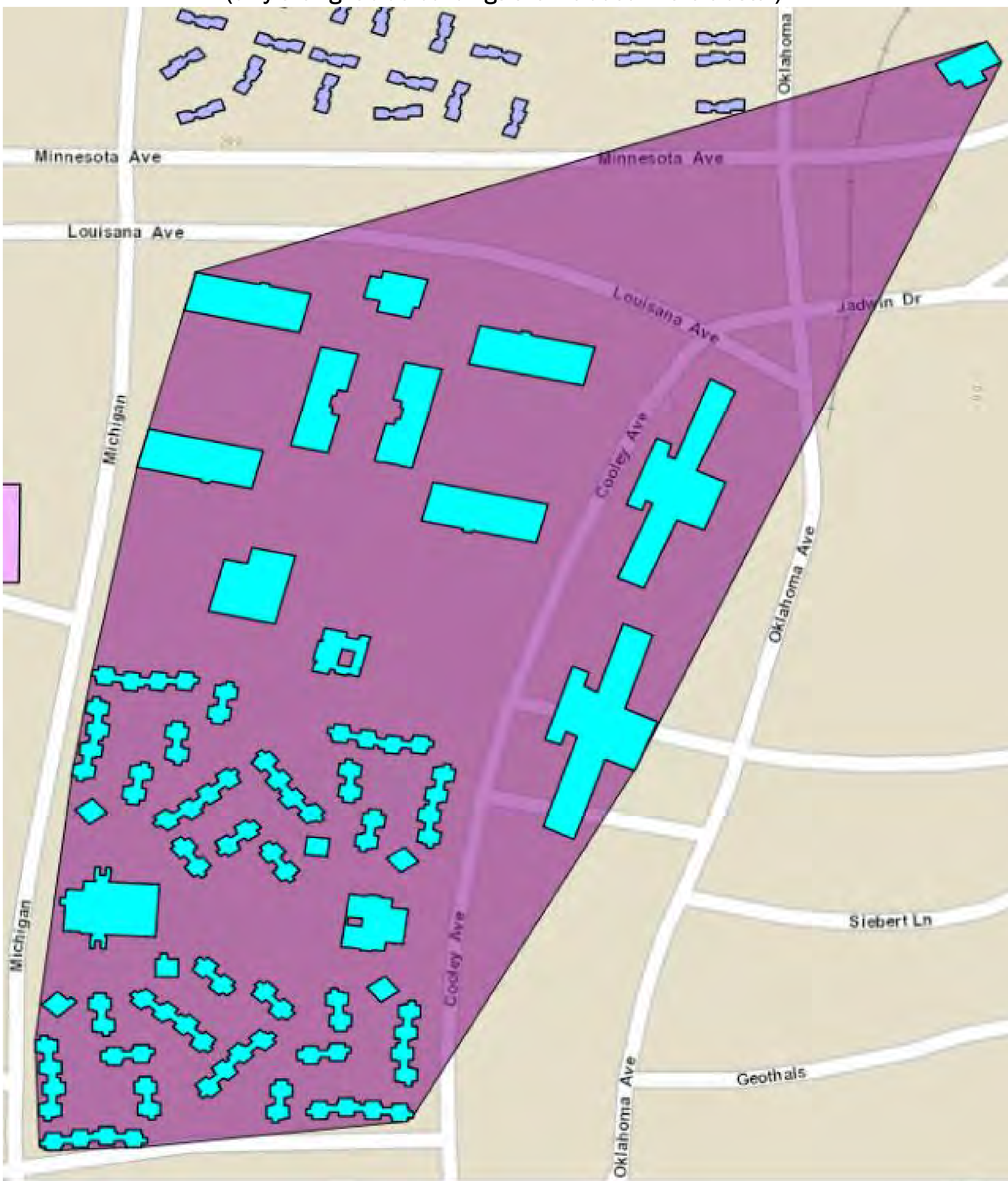
2.7.1 Central plants and distribution

2.7.1.1 Cluster 1 (Specker)

Central plant and distribution: the 48 buildings that make up this cluster (Figure 19) will continue to be served by the Specker central plant. The suggested central plant equipment (as determined by the Net Zero Planner) is shown in Table 34.

This alternative adds an additional air cooled chiller and natural gas boiler capacity. The additional air cooled chiller and boiler capacity were added to meet the capacity and *n plus one* constraint requirements. The *n plus one* constraint requires the maximum load to be met while missing any single piece of equipment. The optimization chose a cheaper, lower-efficiency chiller (COP ~3) to meet this constraint since it is only needed when one of the larger units is down. Efficient base load operation would still be performed by the two existing water cooled chillers. The additional boilers should be viewed as total additional boiler capacity, not a recommendation toward the specific number and sizes given in the table.

Figure 19. Specker cluster with two AIT barracks added (only the light blue buildings are included in the cluster).



The Specker plant distributes through hot and chilled water distribution networks. Hot water leaves the plant at approximately 350 °F and returns at between 250-330 °F depending on the thermal load. Chilled water leaves the plant at approximately 42 °F and returns between 47-54 °F depending on the thermal load.

Table 34. Equipment suggested for Alternative 3 in the Specker plant. Capacities shown for each individual unit.

Equipment	Max Power	Unit	Devices
ACBus1	20,000	kW	1
Air_Elec_Chill_4	300.00	ton pwr	3
Boil0	0.30	MMBtu/hr	4
Boil1	3.40	MMBtu/hr	3
Boil2	8.50	MMBtu/hr	2
ExistingBoilers	23.70	MMBtu/hr	2
ExistingElChillers	949.60	ton pwr	2

2.7.1.2 Clusters 2 and 3

Under this scenario, the South and West clusters use the EEM packages specified for Alternative 2.

2.8 Alternative 4

This alternative involves reducing the outgoing hot water temperature for the Specker and South Cluster from approximately 350 °F to approximately 300 °F. This would be done to enable the use of waste heat from natural gas driven reciprocating engines in the hot water distribution networks. Further work is needed to determine the potential cost and feasibility of this type of transition, but the energy implications and some initial costing are provided here. The energy and cost comparison for the alternatives is presented in the conclusions and recommendations section.

2.8.1 Buildings

The building information is the same as the previous section, Alternative 3, Building EEMs.

2.8.2 Central plants and distribution

2.8.2.1 Cluster 1 (Specker)

Central plant and distribution: The 48 buildings that make up this cluster (see Alternative 3 Specker for the map) will continue to be served by the Specker central plant. The suggested central plant equipment (as determined by the Net Zero Planner) is shown in Table 35.

The Net Zero Planner suggested the addition of approximately 18 additional MMBtu/hr worth of boiler capacity, 3 MW of natural gas reciprocating engine capacity and approximately 900 air cooled chillers. The additional boiler and chiller capacity would allow the central plant to meet its heating and cooling peaks while having any given piece of equipment down. The drop in the outgoing hot water temperature allowed the use of waste heat from the reciprocating engine. This on-site combined heat and power generation leads to much lower source energy consumption for the cluster when compared to the other alternatives. The heat exchangers are needed to capture the waste heat from the reciprocating engine for use in the hot water network.

The Specker plant distributes through hot and chilled water distribution networks. Hot water leaves the plant at approximately 300 °F and returns at between 200-280 °F depending on the thermal load. Chilled water leaves the plant at approximately 42 °F and returns between 47-54 °F depending on the thermal load.

Table 35. Equipment suggested for Alternative 4 in the Specker plant. Capacities shown for each individual unit.

Equipment	Max Power	Unit	Devices
ACBus1	20,000	kW	1
Air_Elec_Chill_4	300.00	ton pwr	3
Boil0	0.30	MMBtu/hr	3
Boil2	8.50	MMBtu/hr	2
ExistingBoilers	23.70	MMBtu/hr	2
ExistingElChillers	949.60	ton pwr	2
HeatE1	34.10	MMBtu/hr	2
HeatE1	34.10	MMBtu/hr	2
NGR_Caterpillar_CHP	3,000	kW	1

2.8.2.2 Cluster 2 (South)

Central plant and distribution: The 27 buildings that make up this cluster (see Base Case South for a map) will continue to be served by the South central plant. The results of the analysis are provided in Table 36.

The Net Zero Planner suggested the addition of 1 MW of natural gas reciprocating engine capacity, approximately 600 tons of air cooled chiller capacity, and approximately 100 tons of absorption chiller capacity. The additional chiller capacity would allow the central plant to meet its cooling peaks while having any single chiller down. The drop in the outgoing hot water temperature allowed the use of waste heat from the reciprocating engine. This on-site combined heat and power generation leads to much lower source energy consumption for the cluster when compared to the other alternatives. The heat exchangers are needed to capture the waste heat from the reciprocating engine for use in the hot water network.

The South plant distributes through hot and chilled water distribution networks. Hot water leaves the plant at approximately 300 °F and returns at between 200-280 °F depending on the thermal load. Chilled water leaves the plant at approximately 42 °F and returns between 47-54 °F depending on the thermal load.

Table 36. Equipment suggested for Alternative 4 in the South plant. Capacities shown for each individual unit.

Equipment	Max Power	Unit	Devices
Abs_Chill_Single_1	100.10	ton pwr	1
ACBus1	20,000	kW	1
Air_Elec_Chill_4	300.00	ton pwr	2
ExistingBoilers	32.60	MMBtu/hr	2
ExistingElChillers	349.70	ton pwr	2
HeatE1	34.10	MMBtu/hr	1
HeatE1	34.10	MMBtu/hr	1
HeatE1	34.10	MMBtu/hr	1
HeatE1	34.10	MMBtu/hr	1
NGR_Jenbach_Large_CHP	1,000	kW	1

2.8.2.3 Cluster 3 (West)

Under this scenario, the West cluster follows the same specifications as Alternative 2.

2.9 Net Zero Energy conclusions and recommendations

Initial analysis shows the potential for significant cost and energy reductions through improvements to the building stock and the three centralized plants considered in this study. The results of this study are "rolled up" to their highest level in Table 37. This table provides a summary of the energy usage that would be expected for each alternative and provides economic data for the fuel use and central plant equipment, but does not currently include the costs related to the building EEMs. A few observations stand out from this data. First, the alternative titled "Building EEMs High" has the lowest energy consumption of any of the alternatives, but will have the highest costs associated with building improvements. Second, among the last three alternatives (all of the alternatives with "EEMs Realistic"), the last alternative represents the lowest equivalent annual cost and energy usage (both site and source). This alternative requires further analysis, but has the potential to provide significant energy and cost savings when compared to the current plan of action (Base Case).

Our recommendation is to implement the building energy-efficiency measures provided in the Alternative 2-4, "Buildings Realistic" as the minimum measures. If the buildings' projects are pushed to higher performance for both the existing with deep retrofits and new construction as high performance, the results will be between these 2 alternatives presented for building EEMs.

Additionally, a continuation of analysis to determine the feasibility of lowering the hot water distribution temperatures of the Specker and South networks should be considered. This temperature reduction would allow the use of waste heat from natural gas driven reciprocating engines to provide heat to the distribution system. This would lower the total cost of providing heat and electricity to the clusters, while drastically lowering their source energy consumption.

This analysis was performed assuming the continued operation of the existing central plant boilers and chillers. An analysis for decision-making when the current equipment fails would be interesting and may provide a financial incentive towards more efficient chiller equipment, such as magnetic levitation chillers. These chillers would significantly reduce electrical consumption, but are not the lowest life cycle cost solution at this time. Additional work is needed to determine whether the magnetic levitation chillers would be life cycle cost effective when the current equipment requires replacement.

Table 37. Summary of the energy and costing results for the six alternatives considered. The total equivalent annual cost column includes central plant equipment, maintenance and operation, and all energy costs, but excludes building improvement (EEMs) related costs.

Scenario	Investment	Total Equivalent Annual Cost (Dollars/Year)	Total Source Energy MWhs/Year	Total Site Energy MWhs/Year
Base Case	261,232,464	28,404,150	600,465	264,752
Baseline	0	22,639,526	497,248	224,963
Building EEMs High	282,177,984	22,331,118	404,417	172,452
Building EEMs Realistic	269,318,240	25,837,242	495,989	224,362
Building EEMs Realistic with AIT Barracks added	263,874,384	24,736,482	493,892	223,703
Building EEMS Realistic with AIT Barracks MTHW	266,081,728	24,336,304	459,666	236,736

3 Net Zero Water

This chapter was authored by Elisabeth Jenicek, Laura Curvey, Jorge Flores, Marianne Choi, and Noah Garfinkle of the ERDC-CERL Energy Branch (CF-E).

3.1 Background

ERDC-CERL and Fort Leonard Wood are in the fourth year of planning and execution in support of installation sustainability. The water project at Fort Leonard Wood emerged from this planning effort with the focus on identifying sustainability goals and objectives and defining a set of tasks to achieve them. The focus on water at Fort Leonard Wood was initiated through a one-day water workshop that engaged personnel from throughout the post, water technology specialists, and regional experts. The agenda for the day included “Army Net Zero Water: What Does It Mean?”, “Regional Water Topics”, “Low Impact Development Approaches”, “Cool Stuff in the World of Net Zero Water”, and “What do we care about with water – what’s next?” The final outcome was a prioritized list of water issues that were important to the installation stakeholders. These issues were used to derive more specific tasks that ultimately led to the Fort Leonard Wood water assessment. Some of the issues identified during the water workshop will be addressed in future Strategic Sustainability Performance Plan (SSPP) projects supporting Fort Leonard Wood.

Specific tasks for the FY 2013 water effort include water balance and water sustainability assessments. The prioritized list from Fort Leonard Wood Water Day revealed an interest in identifying end uses of water at the installation. The purpose of the June 2013 site assessment was to survey water consuming equipment and to collect data and information to ascertain how potable water is used at Fort Leonard Wood. This data is intended to support efforts to reduce overall water use on post.

The site assessment was coordinated by Bryan Parker, Fort Leonard Wood Master Planning. Bryan provided letters of introduction to each team member and utility room access keys to each survey team. Schedules and access to facilities were arranged ahead of time, as much as possible, by contacting Fort Leonard Wood personnel. Some of the survey teams were escorted by appropriate local personnel.

Completed objectives included:

- overview of site assessment to key DPW proponents. Met with water management staff, other DPW personnel, and associated contractors.
- survey of 30 – 50 buildings of different types, collecting information about water-consuming equipment/fixtures and operating schedules. Surveys included photographs of equipment and equipment data collection using the MICA-WET tablet application.
- interviews with personnel from a range of installation directorates, tenants, and reimbursable customers.
- installation of flow recorders on five building water meters to collect longitudinal water consumption data to determine building water use profiles and identify incongruities.
- collection of supporting data needed to create installation water use models.

3.2 Goals and requirements

3.2.1 Federal goals

Army installations are subject to water goals promulgated in public law and executive order and then incorporated into Army policy and directives. Facility water efficiency criteria has changed over time resulting in an array of efficiency standards applicable across the post and even within individual facilities. A listing of federal goals, Army policies, and codes and standards is shown in Table 38. Detailed equipment performance criteria can be found later in this chapter.

Table 38. List of Federal and Army water goals.

Federal Requirement	Water Topic	Water Performance Target
CEQ	Implementing instructions: Water efficiency and management provisions of Executive Order 13514	
EO 13123, June 1999	Reduce water through cost-effective efficiency	FEMP BMPs
EO 13423, January 2007	Water Consumption	Reduce consumption by 2% annually for 16% total by FY15 (FY07 baseline)*
	Water Audits	At least 10% per year every 10 years

* Revised in EO 13514.

Federal Requirement	Water Topic	Water Performance Target
	Products and Services	Procurement of water efficiency products and services, WaterSense®
Energy Independence and Security Act of 2007	Covered Facilities (75%)	Comprehensive evaluations, project implementation, and follow-up
	Post-Construction Stormwater	Restore to predevelopment hydrology
EO 13514, October 2009	Water Consumption	Reduce consumption by 2% annually for 26% total by FY20 (FY07 baseline)
	Industrial, Landscape, Agricultural	Reduce consumption by 2% annually for 20% total by FY20 (FY10 baseline)
	Water Reuse	Identify, promote, and implement water reuse strategies
	Stormwater Management	Implement and achieve objectives from USEPA
Army Policy		
Army Sustainable Design and Development Policy, December 2013	New Construction and Renovation	Achieve 30% reduction compared to baseline IAW American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) 189.1-2009 Outdoor use achieve a 50% reduction
Army Campaign Plan 2014	Major Objective 8-1	3 water related metrics
Army Water Goal Attainment Policy	General water requirements	
UFC 1-200-02 High Performance Bldgs 1 March 2013	Indoor Water	ASHRAE for fixtures/appliances; WaterSense®
	Outdoor Water	Reduce by 50%; ASHRAE when LCC effective
	Water for Heating/Cooling	ASHRAE when LCC effective
	Measurement of Water	Install meters IAW DODI 4170.11
Code/Standard		
EPA WaterSense®	Fixtures, irrigation, PRSV	Establish standards & certify products
ASHRAE 189.1-2009	Fixtures, irrigation, HVAC	Establish performance requirements

Federal water use standards are captured in three key documents: Executive Order 13523, *Strengthening Federal Environmental, Energy and Transportation Management* (2007); the *Energy Independence and Security Act of 2007*; and, Executive Order 13514, *Federal Leadership in Environmental, Energy and Economic Performance* (2009). EO 13523 established water reduction targets, required facility audits, and required procurement of water efficient products and services. EISA 2007 requires comprehensive evaluations of covered facilities with follow-up projects, and established stormwater management requirements. EO 13514 extended water reduction requirements, established conservation targets for industrial, landscape and agricultural use, encouraged water reuse, and addressed stormwater management.

3.2.2 Army policy

Army policy for water efficiency is contained in several documents. All Army facilities must comply with the requirements of the Army Campaign Plan, key objective 8.1. New Army facilities or major renovations must meet the provisions of the Sustainable Design and Development Policy. Federal and Army policy incorporates consensus standards including LEED and ASHRAE 189.1-2009.

The 2014 *Army Campaign Plan* addresses water sustainability under Campaign Objective 8, “Achieve Energy Security and Sustainability Objectives.” Major Objective 8-1, “Enhance Energy and Water Security and Sustainability Strategies.” Major subtasks currently relate to reduction of potable water consumption intensity at permanent installations; achieve energy and water evaluations on 25% of covered facilities annually. Existing metrics are:

- percent of covered square footage that completed water evaluations;
- percent of total water meters installed on appropriate facilities and reporting to MDMS versus total scheduled; and,
- percent reduction in potable water intensity measured in gallons/gross square foot.

The Army’s *Sustainable Design and Development Policy Update* (DA 2013) updates and supersedes the policy of October 2010. The revision applies to “all construction activities on Army installations...regardless of funding source.” Exceptions to the policy are DoD medical funding and privatization initiatives.

UFC 1-200-02, *High Performance and Sustainable Building Requirements*, was signed in March 2013. Water provisions include indoor, outdoor, water for heating and cooling, and metering requirements. Army implementation guidance was signed by HON Katherine Hammack on 16 December 2013 “Sustainable Design and Development Policy Update”.

3.2.3 Standards and codes

WaterSense is a USEPA partnership program that certifies water fixtures that meet rigorous criteria in both performance and efficiency. Specifications and criteria are available for bathroom sink faucets, shower heads, toilets, urinals, landscape irrigation controls, and pre-rinse spray valves.

The U.S. Green Building Council's (USGBC) *Leadership in Energy and Environmental Design* (LEED) Green Building Rating System is a voluntary standard for high performance sustainable buildings. LEED certification validates that a building is a high performing, sustainable structure. Certification also benchmarks a building's performance to support ongoing analysis over time to quantify the return on investment of green design, construction, systems, and materials. All Military Construction, Army (MCA) projects meeting the minimum program requirements for LEED certification are to be planned, designed, and built to be Green Building Certification Institute (GBCI) certified at the Silver level or higher. WE 1, the Water Efficient Landscaping credit and WE 3, the Water Use Reduction (30% reduction) credit are required in all MCA projects.

ASHRAE developed Standard 189.1-2009 *Standard for the Design of High-Performance Green Buildings* in conjunction with the USGBC and the Illuminating Engineering Society (IES). This standard is intended to provide minimum requirements for sustainable or green buildings through the general goals of reducing energy consumption, addressing site sustainability, water efficiency, occupant comfort, environmental impact, materials, and resources. The Army adopted the energy and water standards of ASHRAE 189.1-2009 for all new construction and major renovations through the *Sustainable Design and Development Policy*.

3.2.4 Fort Leonard Wood sustainability goals

The Fort Leonard Wood Integrated Strategic Sustainability Plan contains Strategic Goal 1, sustainable development and redevelopment, that includes Objective 1.2: Efficient use and management of energy and water that is provided from cost-competitive, secure, and renewable sources and Objective 1.3: By 2035, develop new and modernize existing facilities to perform at net-zero with respect to energy, water, and waste while also providing a high quality of life and adaptable work environment (Stumpf et al 2009). Reduced water use is the indicator used to assess progress toward these objectives. The leading measure is number of facilities/year audited and the lagging measure is reduction in water intensity. These objectives suggest a requirement to include education and outreach to all sectors on post.

3.2.5 Water site assessment goals

The goals of the net zero water effort at Fort Leonard Wood are to raise awareness for water issues of concern and to identify ways that water consumption can be reduced. These goals can be achieved by identifying how water is used on post and recommending cost-effective measures to reduce consumption. Measures may include policies, programs, and technologies.

3.3 Baseline: 2012

During the week of June 24-28, 2013, four ERDC-CERL teams visited Fort Leonard Wood to conduct a water site assessment. The goal of the assessment was to survey a cross-section of buildings, to identify water using technologies, to interview Fort Leonard Wood staff about water use practices, all supporting development of an estimate of water consumption by end use. The assessment team surveyed 25 buildings and installed water flow recorders on five building-level meters with the goal of collecting water flow data every minute for a time period not to exceed three months. The team also conducted interviews with Fort Leonard Wood personnel to determine water end uses not clearly linked to building footprint (e.g., irrigation, bulk water point, and specialized training needs.)

3.3.1 Reported water use

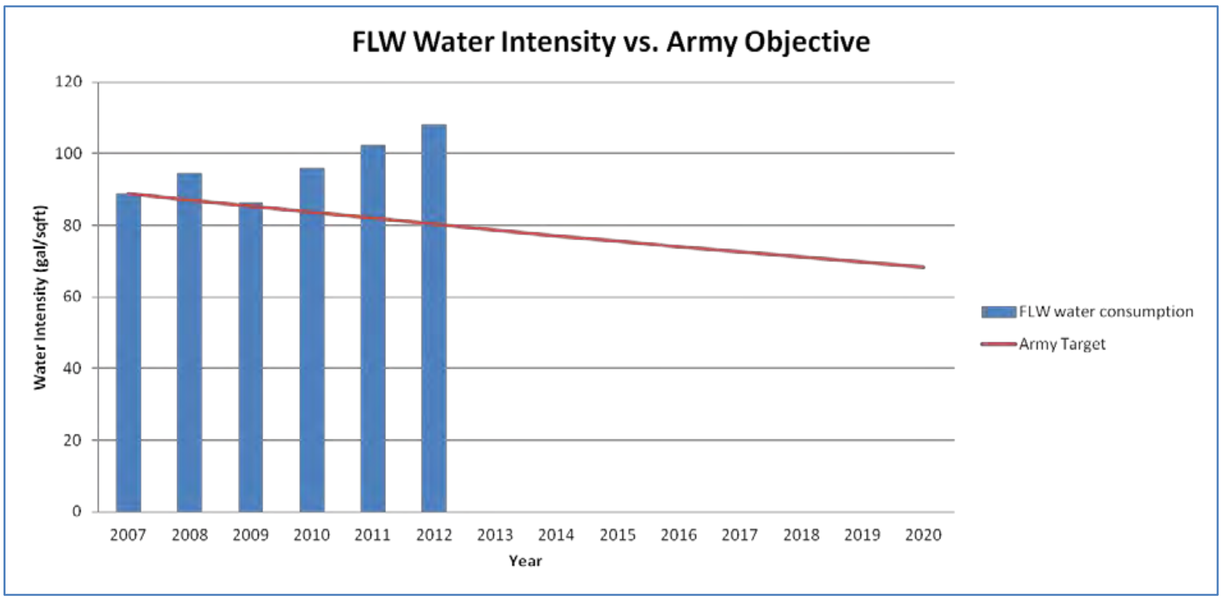
The Fort Leonard Wood water system is comprised of a drinking water treatment plant with a capacity of 5 MGD and 780,105 feet of distribution piping. The DWTP produces 2.6 – 2.8 MGD from its withdrawal from the Big Piney River. Additional water sources on post are untreated well water and untreated withdrawals from the Big Piney. A detailed description of the water infrastructure is in Annex 3-1: Water system description.

Reported water use for Fort Leonard Wood was obtained from two sources: the Fort Leonard Wood Department of Public Works and the Army Energy and Water Reporting System (AEWRS) database. AEWRS was also the source for historical building square footages required for water intensity calculations. In addition to sustainable water use targets, Fort Leonard Wood is also subject to federal regulations regarding water use and water conservation targets. Current federal targets consider water consumption per square foot of conditioned area, referred to as water intensity. Water intensity is used as the metric for both Army and federal water conservation targets.

3.3.1.1 Demand

Figure 20 shows the calculated water intensity for Fort Leonard Wood from Fiscal Years 2007 to 2012. The line beginning at 2007 presents the two percent annual reduction (from a baseline of 2007 through 2020) in water consumption intensity set as a target for installations. As can be seen in Figure 20, Fort Leonard Wood will require additional actions in order to come into compliance with this water intensity requirement.

Figure 20. Fort Leonard Wood water intensity (water consumption divided by square footage) compared to mandatory reductions in water intensity (EO 13514).

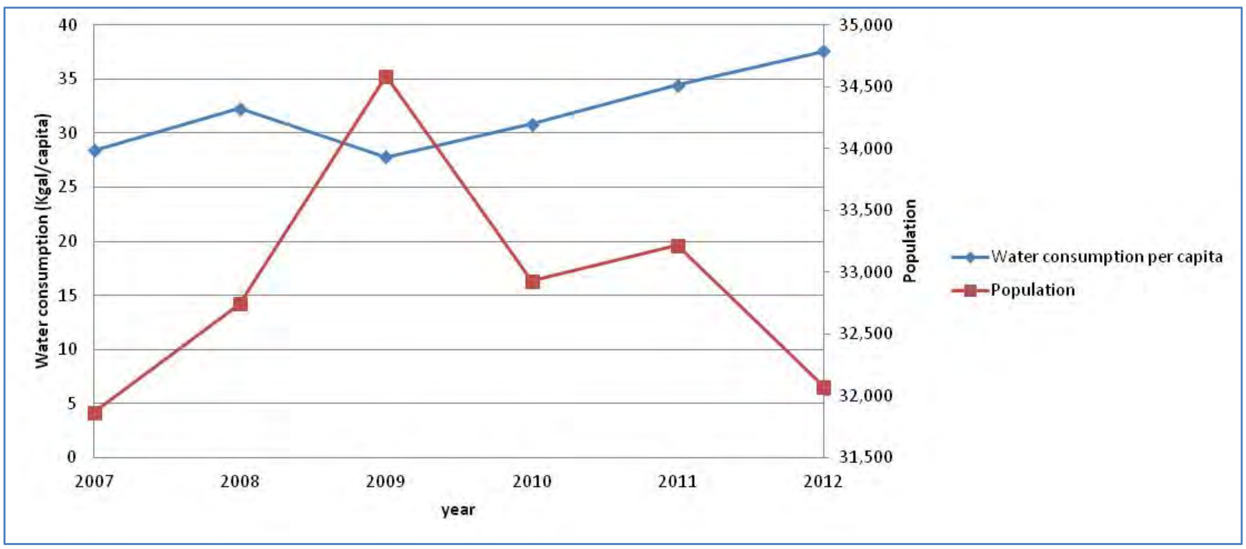


Source: AEWRS 2013

While water intensity is measured in terms of square footage, it is clear that many water demands- with the clear exception of irrigation- are driven by people rather than area. Figure 21 calculates the average annual water consumption per capita at Fort Leonard Wood from 2007 to 2012 shown with the blue line and left axis. As reference, the total population trend for Fort Leonard Wood during the same period is shown with the red line and right axis. Despite some significant improvements in 2009, it appears that Fort Leonard Wood's water consumption per capita has continued to rise in recent years even while the installation population has declined.

A variety of factors must be considered when interpreting the data contained in Figure 21. If significant water demands are process or area driven- as opposed to population driven, it would make sense for a shrinking population to absorb a greater share of the installation's water demand. Additionally, a shrinking population may help to offset the total affect of rising per capita consumption. However, in order to meet Fort Leonard Wood's demand targets, it is clear that the drivers of water demand must be investigated and an effort made to decrease both total and per capita consumption.

Figure 21. Comparison of annual water consumption per capita to installation population.



Source: ASIP 2013, AEWRS 2013.

Figure 22 and Figure 23 expand the investigation of Fort Leonard Wood's water consumption patterns over time by exploring climate variables that may help to explain water use trends. Water use varies with weather for both population driven uses (showers, swimming pools) and other uses (irrigation, exterior washing). Figure 22 compares the installation's reported water production at the drinking water treatment plant and disposal at the waste water treatment plant with the average monthly temperature between April 2007 and September 2012. Clear correlations can be seen between rising mean temperature and both water and wastewater production, as would be expected. Higher temperatures could drive higher water consumption for the end uses mentioned above. Additionally, instances where the amount of drinking water treated exceeds the amount of wastewater treated can indicate high rates of irrigation or drinking water. A continuous discrepancy can point to system leakage.

Figure 22. Monthly quantities of water processed at drinking water treatment and waste water treatment plants, overlaid with monthly mean temperatures. Source: NOAA 2013, FLW 2013.

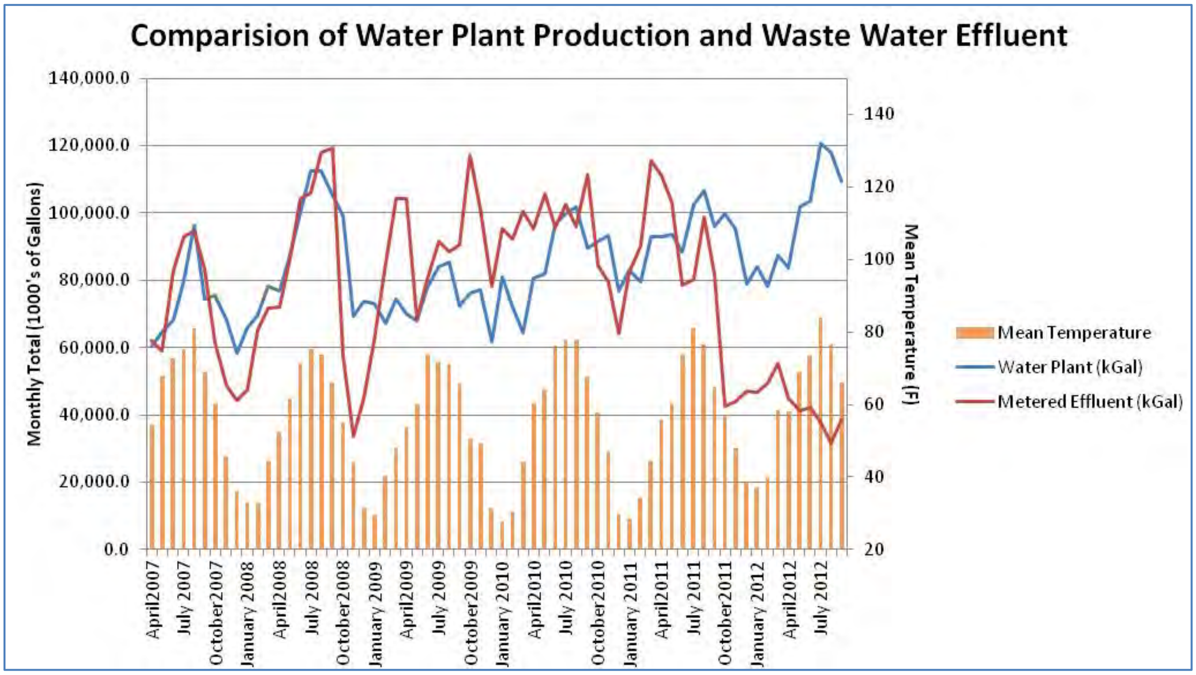
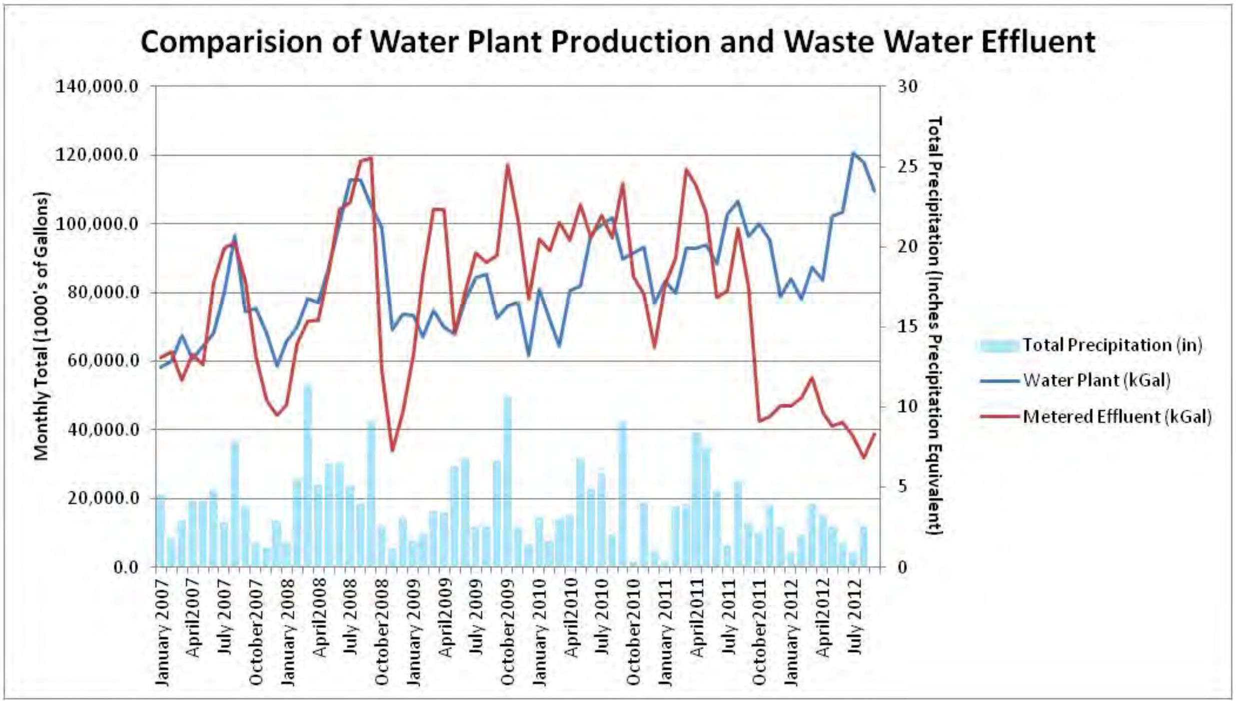


Figure 23 compares the same water and wastewater consumption data contained in Figure 22 with each month's total precipitation. While precipitation is less consistent over time than temperature, and further information is required, it appears that many high-rainfall months are accompanied by increases in wastewater production. This is of potential concern because- to the best of our knowledge- the wastewater treatment plant metered effluent does not include storm water. If this is true, this information could suggest that leakages in Fort Leonard Wood's wastewater distribution system are allowing introduction of rainwater during storm events, causing the installation to treat- and pay to treat- water that is outside of the design scope of the system.

Figure 23. Monthly quantities of water processed at drinking water treatment and waste water treatment plants, overlaid with monthly precipitation equivalent. Source: FLW Airport 2013, FLW DPW 2013.



3.3.1.2 Water Use by Facility Type for NZI Analysis

Table 39 presents baseline and Base Case facility type breakdowns. Models of these facility types augmented building meter data gathered during the site assessment and water use factors from the American Water Works Association (AWWA) (AWWA 2002) in order to estimate water end use factors for Fort Leonard Wood.

The facility types considered for the water analysis are a subset of the entire installation building stock and mirror those considered for the energy and waste assessments. Water end use was determined using a variety of methods as there is insufficient building meter data. The American Water Works Association Research Foundation (AWWARF) conducted research into water use by building type. These use factors were updated, where possible, with information gained during the site assessment.

Table 39. Facility list with population and infrastructure data.

	Baseline			Base Case			Comparison		
Facility Type	Conditioned Area (sq ft)	Number	Occupancy	Conditioned Area (sq ft)	Number	Occupancy	Change in Area	Change in Number	Change in Occupancy
ARC[1]	20,726	2	588	20,726	2	588	0%	0%	0%
BdeHQ[2]	529,488	19	1,117	529,488	19	1,117	0%	0%	0%
BnHQ[2]	2,089,269	149	4,407	2,146,089	145	4,526	3%	-3%	3%
CDC[4]	48,076	2	5,652	48,076	2	5,652	0%	0%	0%
COF[2]	315,606	16	665	340,248	18	716	7%	11%	7%
DFAC[8]	309,130	17	9,163	387,564	18	11,487	20%	6%	20%
GPW[6]	411,755	50	100	411,755	50	100	0%	0%	0%
Religious[6]	27,463	1	100	27,463	1	100	0%	0%	0%
TEMF[6]	757,728	72	1,000	734,381	70	969	-3%	-3%	-3%
Training Barracks[7]	3,005,143	100	8,501	4,422,154	116	12,509	32%	14%	32%
UEPH[9]	162,258	64	3,033	185,505	67	3,427	13%	4%	13%

Source: Army Net Zero Planner (2013).

[1]ASIP Reserve Component

[2]6189 Army Military Permanent (ASIP)*Area/($Area_{BnHQ}$+ $Area_{BdeHQ}$+ $Area_{COF}$) Future population scaled based on change in area

[3]ASIP

[4]Includes all school-age children on post (COP Dependent Calculations)-some may be off post

[6]Estimate

[7]Barracks Capacity Report (20 September 2013)

[8]Estimated from consolidated monthly dining headcount summary- April 2013 (total/30days/3meals)

[9]COP Spreadsheet Dependent Calculation 2012 (7737 Permanent military-[11760 military family/2.58people per average US Family Household (Census)])

Estimates of water end use are based on AWWA building water use factors, building audits, and information about non-building water use obtained during interviews with personnel (USACE 2010). Table 40 shows this estimate, in total water demand (1,000s of gallons) per day.

Table 40. Baseline water consumption by end use.

Using Sector	Gallons/ Day/ Occupant	Number	Units	Consumption (MGD)
Family Housing[2]	100	2,234	Occupants	0.62
Barracks[1]	55	18,970	Occupants	1.04
Dependent Schools[1]	55	2980	Occupants	0.16
Medical[3]	40	1,236	Building	0.01
Industrial and Maintenance[1]	30	700	Building	0.08
Transient Housing/ Lodging/UEPH[2]	50	150	Building	0.22
Administrative/ Moderate Users[1]	30	1204	Building	1.5
Community and Commercial: Non-food related (indoor)[1]	6	629	Building	0.11
Community and Commercial (food-related)[1]	10	906	Building	0.03
Storage[1]	50	10	Building	0.00
Total Daily Water Use in MGD				3.78
High Water Use Facilities				
Using Sector	**Quantity**	**Number**	**Units**	**Consumption (MGD)**
Irrigated/ Improved Land[1]	68	529	Acres	0.01
Training (Pools, Wash Racks[2])	1	1400	Building	0.16
Losses[4]	10% of total	3.78	MGD	0.39
Total Annual Water Use in MGD				0.56
Baseline Annual Average (MGD)				4.34

* The above values are preliminary. New models are being adjusted- in part based upon the buildings currently being metered at Fort Leonard Wood (discussed below)

[1]ERDC-CERL Models

[2]Estimates resulting from site surveys and inquiries at Fort Leonard Wood

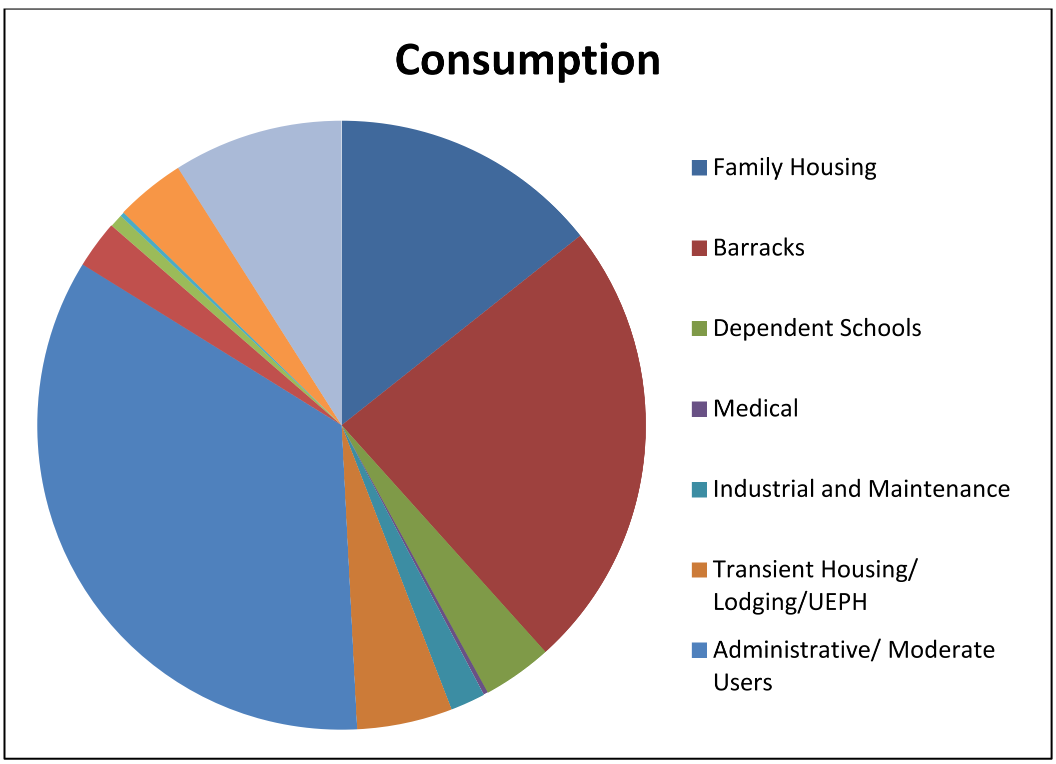
[3] Approximately 6,400 cubic feet peak daily flow from meter at the troop clinic (Building 885, Figure 4.6) , estimated 150 daily total occupants, yields approximately 40 gallons per occupant per day

[4]American Water Works Association, 2009

The current baseline estimate of total potable water consumption for the facility types comprising the study- along with estimates of large water users and conservative system losses- yields approximately 73,890 kgals per month if total flows are evenly distributed. This total can be compared to Figure 22 and Figure 23, which plot total potable water demand (actual) as between 60,000 and 120,000 kgs per month over the time period described by the data set (2007-2012). This comparison serves as an important model-verification step, as the subset of water users studied- which ERDC-CERL believes to represent a large portion of installation water demand- falls within the range of monthly water consumption expected for Fort Leonard Wood.

An additional water end use disaggregation was carried out using methods developed for a series of Army Installation Water Sustainability Assessments (USACE 2010). This analysis employs water use factors based on facility category code. A listing of facilities with category codes and square footage was obtained from the Army's HQIIS system. The results of this analysis are shown in Figure 24.

Figure 24. Water end use estimate based on facility square footage.



3.3.1.3 Supply

Fort Leonard Wood receives water from three sources: direct withdrawal from the Big Piney River with no treatment; direct withdrawal from on-post wells with no treatment; and water withdrawn from the Big Piney River, treated at the drinking water treatment plant, and distributed throughout the post as potable water. End use estimates for each water source are listed in Table 41.

Table 41. Water supply sources and estimated quantities.

End Use	Water Supply Source		
	Big Piney River (DWTP)	Big Piney River (untreated)	Wells (untreated)
Big Piney golf course irrigation		66.9 MG/year*	
Quarry operations			TBD
Potable water system	1,206 MG/year**		
TOTAL USE	1,206 MG/year	66.9 MG/year	

* Estimated using AFCEE calculator
** FY 2012 FLW water data

3.3.2 Site assessment findings

A water site assessment was conducted at Fort Leonard Wood from 24-28 June 2013. Building audit teams sampled fixtures, photographed buildings and equipment, and accessed mechanical rooms for data collection. The interview team collected data and information about non-building water use and high water intensity activities.

3.3.2.1 Building audits

A total of 25 buildings of varying vintage, function, and equipment were audited. Audit teams used tablet technology containing the MICA:WET software to record data, information, and photographs about each building's water equipment. The locations of the audited buildings are shown in Figure 25.

Figure 25. Map of facilities visited during June 2013 water site assessment.

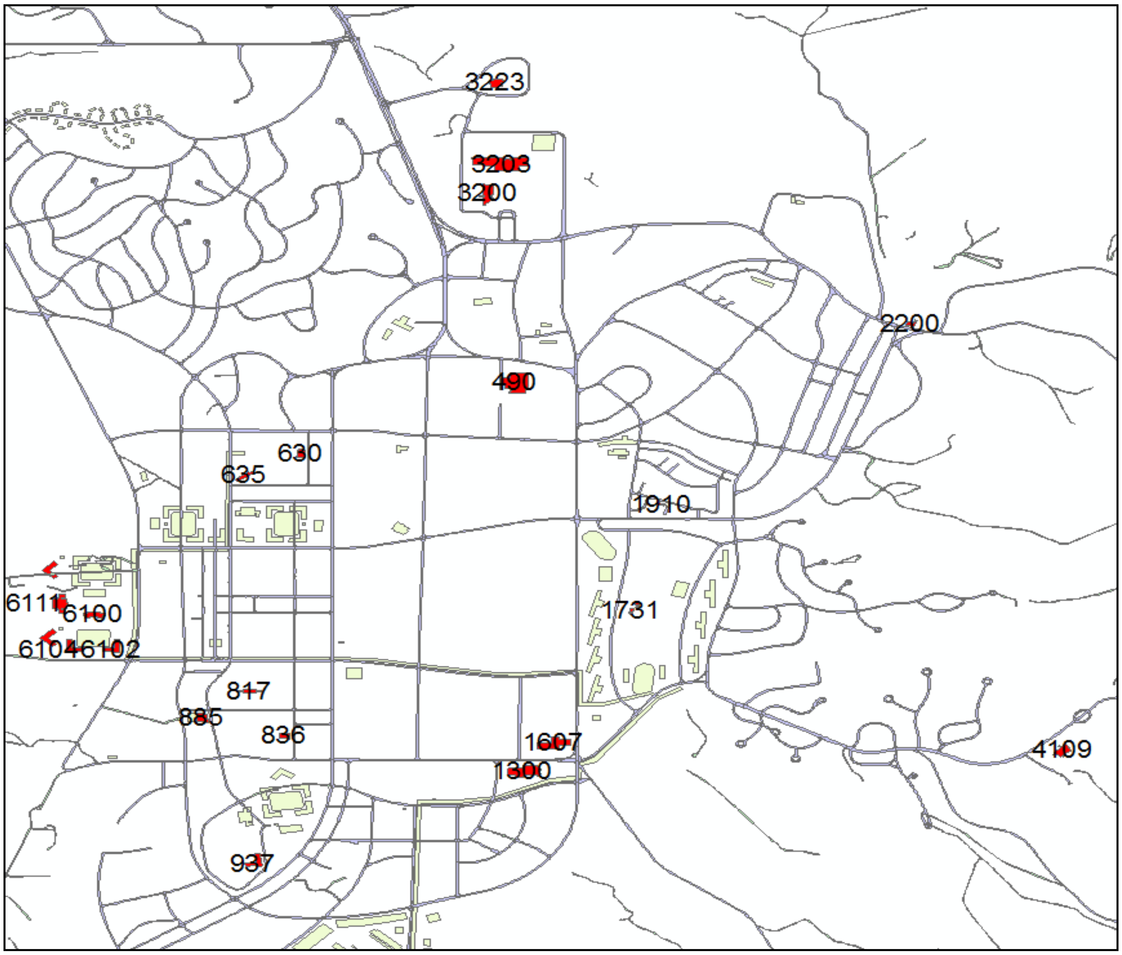


Table 42 lists each of the buildings surveyed and provides information intended to inform water system retrofit decisions.

Table 42. List of facilities visited during June 2013 water site assessment.

Bldg	Bldg Type	Const Date	Upgrade to efficient showerheads	Upgrade to efficient Bathroom Faucets	Maitenance Toilet/Urinal Program	Reference tables of equip
635	Trainee Barracks, 3rd Chem	1963	Yes	Yes	Yes	7,8,9
817	Trainee Barracks, MP Bde	1966	Yes	Yes	No	7,8,9
901	New Barracks, MP Bde	?	No	No	No	7,8,9
937	Trainee Barracks	2004	Yes	Yes	Yes	7,8,9
1731	Trans UPH AIT	1979	Yes	Yes	Yes	10,11,12
1732	Trans UPH AIT	1979	Yes	Yes	Yes	10,11,12
1789	AIT Barracks	?	No	No	No	10,11,12
1910	Enlisted UPH	2008	Yes	No	No	10,11,12
6102	Trainee Barracks 1st En Bde	2010	No	No	No	5,6
6104	Trainee Barracks 1st En Bde	2010	No	No	No	5,6
6105	Trainee Barracks 1st En Bde	2013	Yes	Yes	No	5,6
6147	Trainee Barracks 1st En Bde	2013	No	No	No	5,6
630	DFAC	1964	N/A	Yes	Yes	
836	DFAC	1967	N/A	Yes	Yes	
1784	DFAC	1979	N/A	No	Yes	
3223	DFAC	1999	N/A	Yes	Yes	
4109	Consol Open Dining, MWR	?	N/A	No	No	
6111	DFAC	2011	N/A	Yes	No	
490	Food Court	1995	N/A	No	Yes	
602	Pool, MWR	1961	Yes	Yes	No	
1300	Indoor Pool, MWR	1300	Yes	Yes	Yes	
1607	Museum	1970	N/A	No	Yes	
3203	MSCOE	1999	Yes	Yes	Yes	13
6100	Bn HQ, 1st En Bde	2010	No	No	No	
6103	BCOF, 1st En Bde	2010	No	No	No	
11480	TEMF	?	Yes	Yes	No	
11470	Comp Ops Facility	?	No	Yes	Yes	

3.3.2.2 Barracks

Team One audited a number of 'Starship Barracks' that were built in 2011 and 2012. These barracks are designated 6147, 6102, 6104, and 6105. All of the barracks contained building-level water meters. Meter readings were recorded for each building and flow recorders were connected to the water meters of buildings 6147 and 6102(**). The floor plan for facilities consisted of gang-style bathrooms. Barrack 6102 was metered and for the month of June to July, over 27 days, consumption was 48 kgal of water.

- **Toilets**: High efficiency 1.28 gallons per flush (gpf) Zurn flushometer toilets were predominantly present in barracks 6147, 6104, 6105. Standard 1.6 gpf Sloan flushometer toilets were in 6102. Except for two toilets; one in room 204 on the far right in barrack 6147 which flushed at 6.5 gpf, and one in the men's room on the first floor of 6102 which flushed at 2.5 gpf, the rest of the measured toilets performed as stated on the appliance nameplate.
- **Faucets:** High efficiency faucet aerators of 0.5 gallons per minute (gpm) were uniformly installed in barracks 6147, 6104, and 6102. Across the all the barracks the 0.5 gpm aerators performed to rating. However, the standard aerators of 2.2 gpm which were uniformly installed in 6105 performed uniformly below rating averaging 1.38 gpm (Table 43).

Table 43. Performance of bathroom faucets audited by team 1.

Barrack	Faucet Rated GPM	Average Measured GPM	% of Rated GPM
6102	0.5	0.5	100
6104	0.5	0.5	100
6105	2.2	1.38	62
6147	0.5	0.5	100

- **Showers:** High efficiency 1.5 gpm shower heads were installed primarily throughout 6102, 6147, and 6104. In 6102, ten 2.2 gpm replacement heads were present in showers on the third floor. In 6104, one 2.2 gpm replacement head was present on the first floor. In barrack 6105, eighty of the 128 total gang-shower heads were 2.2 gpm Zurn showerheads. The rest were 1.5 gpm Zurn showerheads. Almost all of the Zurn 1.5 gpm showerheads performed as rated. However, none of the Zurn or Sloan 2.5 gpm showerheads performed as rated. In fact, measured flow rates from 1.0 to 2.0 gpm were recorded with the average measured flow rate as 1.4 gpm (Table 44).

Table 44. Performance of bathroom showerheads audited by team 1.

Barrack	Shower Rated GPM	Average Measured GPM	% of Rated GPM
6102	1.5	1.5	100
6104	1.5	1.5	100
6105	2.5/1.5	1.4/1.5	93/100
6147	1.5	1.5	100

- **Urinals:** No urinals were present in the Starship barracks.
- **Hot water temperature** at the Starship barracks averaged out to around 102 degrees Fahrenheit amongst 51 faucets measured. Average ambient water temperature measured to 73 degrees. Seven faucets within 6102, 6104, and 6147 that were generally located nearer to the hot water heater measured between 126 and 128 degrees. Faucets located on the opposite side of the building measured as low as 77 degrees even after running faucets for three minutes.
- **Pressure** recorded at the third floor in building 6147 was 38 pounds per square inch (psi).

Team Two audited training barracks 635, 817, 901, and 937. Of the four barracks buildings, 901 is a new building.

- **Toilets:** 635, 817, and 937 all had 1.6 gpf rated toilets. Barrack 817 toilets performed close to rating with an estimated 2 gpf measured flush. Barracks 635 and 937 1.6 gpf rated Sloan flushometer toilets performed poorly with a measured average of 6.5 gpf for barracks 635 and 9.85gpf for barracks 937. The measured water pressure at barrack 937 was 47 psi which should be sufficient to close a properly working diaphragm valve on a flushometer toilet. These flush durations suggest that the diaphragm within the flushometer needs to be replaced in order for the toilets to perform as rated. Barracks 901, the new one, contained 1.28

gpf rated Zurn flushometer toilets and they performed as rated. Results are shown in Table 45.

Table 45. Performance of bathroom toilets audited by team 2.

Barrack	Toilet Rated GPF	Average Measured GPF	% of rated GPF
635	1.6	6.5	406
817	1.6	2	126
901	1.28	1.28	100
937	1.6	9.85	615

- **Faucets:** The following table shows the variety and performance of the faucets audited in barracks 635, 817, 937, and 901. Most of the faucets did not perform as rated. However, of the high efficiency 0.5 gpm faucets in building 901, 50% of the faucets did perform as rated compared to zero percent of the higher flow rated faucets in barracks 635, 817, and 937. That being said, the flow rate of the lower efficiency faucets in 635 and 817 are still at least twice the flow rate of the high efficiency 0.5 gpm rated faucets. Thus, it would likely be cost effective to upgrade the aerators in barracks 635 and 817 (Table 46).

Table 46. Performance of bathroom faucets audited by team 2.

Barrack	Faucet Rated GPM	Average Measured GPM	% of rated GPM
635	1.5 / 2.2	1.1/1.4	78/63
817	2.2	1.5	68
901	0.5	.44	88
937	1.0	0.6	60

- **Showers:** Barracks 635, 817, and 937 contain standard 2.5 gpm Sloan showerheads. Measured showerhead performance at 635 and 937 averaged 64% of their rated gpm at 1.6 gpm. Barrack 817 showerheads performed even lower 1.2 gpm. Condition assessments noted some to extensive amount of calcification on the showerheads in each of these barracks. Barrack 901's high efficiency 1.5 gpm Zurn showerheads performed nearly as rated with an average flow rate 1.425. These newer showerheads show little or no calcification. Since the 2.5 gpm and 1.5 gpm rated showerheads have very similar measured flow rates due to calcium build up it would be difficult to justify switching out showerheads to save water. However, it should be noted that replacement showerheads should be rated 1.5 gpm to ensure performance and lower flow rates continue. Results are shown in Table 47.

Table 47. Performance of showerheads audited by team 2.

Barrack	Shower Rated GPM	Average Measured GPM	% of rated GPM
635	2.5	1.6	64
817	2.5	1.2	48
901	1.5	1.425	95
937	2.5	1.6	64

- **Urinals:** Twelve flushometer urinals were accounted for in barracks 635 and one in barracks 817. All of the urinals in 635 were rated 1 gpf. However, 66 % of these had extended flushes with an estimated 7 gpf. Water pressure measured at 60 psi which is sufficient for diaphragm valves to shut. Thus, it is likely the diaphragms in the flushometers need to be replaced to perform properly.
- **Hot water temperature** at barracks 635, 817, 901, and 937 ranged from 85 to 136 degrees F. The average hot water Fahrenheit temperatures at the barracks were 130 F for 635, 119 F for 817, 96 F for 901, and 104 F for 937. To avoid scalding and unnecessary heating, the water at the fixtures should be no more than 120 F degrees. Barracks 635's water heater is set too high and should be adjusted to 120 F.
- **Water Pressure:** Water pressure measured at the buildings is as follows: 60 psi at barracks 635, 48 psi at barracks 817, 90 psi at barracks 901, and 47 psi at barrack 937.

Team Three audited Unaccompanied Personnel Housing (UPH) transient barracks 1731,1732, enlisted UPH barracks 1910, and AIT barracks 1789. Due to limited access, only one restroom was audited in the UPH 1731 and 1732 barracks. If the one restroom were considered a true representation then it would show that the toilets, faucets, and showerheads were of standard, but not high efficiency. They did not perform as rated. The AIT barracks consisted of approximately 40 rooms. Both the AIT and UPH barracks consisted of dorm room layouts with each room having its own bathroom.

- **Toilets:** Sampled flushometer toilets from UPH barracks 1731 and 1732 indicate extended flush duration. However, the water pressure was not measured at these locations to determine if the buildings are experiencing a lack of pressure. Therefore, without additional samples and pressure measurements the reason for higher gallons per flush is unclear. AIT barracks 1789 is a new building that contains high efficiency 1.28 gpf Sloan flushometer toilets that are performing as rated. The sample UPH barrack 1910 contained a tank gravity flush toilet rated at 1.6 gpf. For the audit, it is assumed, without noticeable consistent water flow, the toilet is performing as rated (Table 48).

Table 48. Performance of bathroom toilets audited by team 3.

Barrack	Shower Rated GPM	Average Measured GPM	% of rated GPM
1731	1.6	3	187
1732	1.6	2.5	156
1789	1.28	1.28	100
1910	1.6	N/A	

- **Faucets:** Bathroom faucet measurements were not recorded for UPH barracks 1910. The sampled bathroom faucets in 1731 and 1732 indicate both 2.5 and 1.5 gpm, respectively. Rated faucets performed well below their rating with a flow rate not much higher than the high efficiency 0.5 gpm faucets. The high efficiency 0.5 gpm American faucets performed as rated. Results are shown in Table 49.

Table 49. Performance of bathroom faucets audited by team 3.

Barrack	Faucet Rated GPM	Average Measured GPM	% of rated GPM
1731	2.5	0.6	24
1732	1.5	0.7	46
1789	0.5	0.5	100
1910	N/A		N/A

- **Showers:** Measured shower unites in the UPH barracks 1731, 1732, and 1910 all performed below their 2.5 gpm Delta rating. Their flow rate is consistent with other non-efficient barrack showerheads through Fort Leonard Wood. Their flow rate is also close to the high efficiency 1.5 gpm Niagara rating making comparative savings somewhat moot. As mentioned above, regardless of the lower performance, replacement showerheads should be consistent with the high efficiency standard in order to retain lower water demand (Table 50).

Table 50. Performance of bathroom showerheads audited by team 3.

Barrack	Shower Rated GPM	Average Measured GPM	% of rated GPM
1731	2.5	1.2	48
1732	2.5	1.5	60
1789	1.5	1.5	100
1910	2.5	1.7	68

- **Urinals:** No urinals were present in these barracks
- **Hot water temperature:** Hot water temperatures in the UPH barracks was an average of 117 degrees F. During the audit the AIT 1789 barracks were not occupied, but recently completed construction. The average hot water temp for 1789 was much lower with 79 F. This is likely due to a lowered setting on the water heater to conserve energy until occupation.*
- **Water Pressure:** Water pressure was not measured at these barracks.

3.3.2.3 Dining facilities (DFAC)

Fort Leonard Wood has 14 dining facilities that serve approximately 1.1 million meals per month, 180,000 of which are meals prepared for soldiers training in the field. On average approximately 6,000 soldiers are fed three meals a day supporting up to 48 companies at a time. Each meal event takes approximately 90 minutes to prep with clean-up and prep in between each event. Although Company sizes vary between 80 and 250 soldiers, the planning rule of thumb for preparation for Fort Leonard Wood DFAC is 200 (Bill Moffitt, interviewed by Sue Bevelheimer, June 28,

* Optimum hot water temperature should be selected to prevent scalding and Legionella growth.

2013). This will help determine estimates for daily meals served. Federal water use indices, developed from the 1996 AWWA estimates, assumed that the average meal at a cafeteria requires somewhere between 10 and 20 gallons of water per meal served (15 actual)*. These are preliminary estimates and may be adjusted in lieu of metered data. Since the AWWA estimates are almost 20 years old and plumbing codes have changed substantially since these indices were created, it is assumed that equipment efficiency has reduced water demand per person overall. This report will assume 10-12 gallons per meal served. A common sight noted throughout the audits was leaking pre-rinse spray valves. These items take a lot of abuse and tend to last no more than a year before breaking. Comments from dining facility managers suggest that they should be replaced more frequently. However, the paperwork process to request purchases or maintenance is complex and prohibitive. So the leaking pre-rinse spray valves are left in place.

3.3.3 DFAC 630

This DFAC supports five Companies Monday through Sunday. According to their meal plan, they serve about 1,100 persons per meal per day. Using three meals a day (total 3,300) and 12 gallons per meal, about 39,600 gpd and 14.5 million gallons per year (MGY) are used. However, the number of people served per day is highly variable depending on the training schedules and the types of training. During the audit there were some leaks observed from the pre-rinse spray valves at 0.75 gpm. The pre-rinse spray valves are used approximately six hours a day creating an additional demand of 270 gpd (98.5 kgal/yr) per valve beyond their regular use. It was noted that one ice machine was out of service for two months and has not been used. The main steamer used to cook was with the large and small steamer kettles, not included in the fixture inventory. Water use was also observed for the hot serving lines which are heavily used for each meal. DFAC personnel suggested that foot lever-operated sinks would save time and water, and be more sanitary.

3.3.4 DFAC 836

This DFAC serves eight companies. The day of the water audit, a total of four companies were served during lunch (3 - field feeds, 1 - MRE). A total of eight companies were served for dinner (6- in house, 2 – field feeds). It

* http://www1.eere.energy.gov/femp/program/waterefficiency_useindices.html

is assumed eight companies are served for breakfast and dinner regularly. Four companies are served for regular served lunch. Together 4,000 meals per day are served creating an estimated 48,000 gpd and 17.5 MGY demand. The commercial dishwasher is an Insinger Speeder 86 RPW which can wash 277 racks/hour at 0.52 gal/rack.* This washer is operational approximately six hours per day requiring 865 gpd.

3.3.5 DFAC 1784

Observations during the Building 1784 audit indicate that some dishwashing functions are performed by hand as some pots are too big to fit in the commercial dishwasher. The process includes personnel rinsing large pots and pans with a pre-wash valve and then moving items to sinks to manually wash and rinse. The pre-wash valve was continuously on during the wash cycle. The condition of the pre-wash valve was poor and leaked. However, when the handle was squeezed the leak stopped. Discussion with the DFAC personnel indicated that consumption, including field chow, is based on the training schedule. This can fluctuate from month to month, e.g., June 2013. When asked about how often the commercial dishwater was used each day, personnel noted that it runs continuously throughout the day. The Insinger CS-5 commercial dishwasher can wash 60 racks/hour at 1 gallon/rack.† Based on breakfast, lunch, and dinner, it is estimated that the dishwasher is in use for at least 12 hours, requiring 720 gpd. The capacity of the building is based on number and configuration of seating. We counted 72 tables with eight chairs resulting in a seating capacity of 576. It was reported by kitchen personnel that approximately 2,200 meals are served per day for an estimated demand of 26,400 gpd and 9.6 MGY.

3.3.6 DFAC 3223

Approximately 1,200 meals are served only Monday through Friday creating an estimated demand of 14,400 gpd when in use and 3.75 MGY based off of 260 operational days per year. None of the ice machines were working and leaks were found in the dishwasher, faucet, and pre-rinse spray valve.

* http://www.restaurantequipmentmart.com/insinger-speeder-86-3-rpw-277-rack-hr-conveyor-dishwasher.html

† http://www.foodservicewarehouse.com/insinger/cs-5/p2260.aspx

3.3.7 4109 Consolidated open dining

During the audit of building 4109, contractors were working on plans to rehabilitate both the women's and men's bathrooms which include the installation of new faucets, toilets, and urinals. Both bathrooms serve all the functions of the building which include a bar and restaurant, large event spaces, and administrative duties. The numbers of meals served daily is irregular since 4109 is more of a restaurant and conference center and does not serve nearly the numbers as the training dining facilities. Metered data retrieved shows that during the month of June/July the monthly demand was approximately 103Kgal for a 27 day period, giving an average of 3.8 kgal/day.

3.3.8 DFAC 6111

Building 6111 is a two story dining facility built in 2012 and operates Monday through Sunday. Much of the existing equipment is new and relatively efficient. This facility serves approximately 5,000 meals a day creating an approximate demand of 60,000 gpd and 21.9 MGY. The pre-rinse spray valves, food processors, and the dishwashers are running at a minimum of six hours a day. The main pre-rinse spray valves used for cleaning cookware leaked at 0.5 gpm throughout the hours of operation. There were two food disposals in addition to the food pulper. The food disposal is in constant use during cleaning and prepping food. The use of a food pulper in conjunction with the tray washer recycled tray rinse water helps to reduce the amount of food waste sent to landfills. Building 6111 contains 24 soldier hand-washing stations which consist of sinks with motion-detection faucets. As trainees surged through the line, the 24 faucets likely run at least 30 minutes constantly per day at a temperature of 120 °F. Their flow rate is 2.2 gpm with a daily demand of 1,585 gpd or 578 kgal/year. Installing 0.5 gpm aerators at these hand washing stations would save over 1,200 gpd and 445 kgal/year.

3.3.8.1 Administrative buildings

Administrative buildings are characterized by office use and possible classroom training. The vast majority of water use at these buildings is from restrooms, unless the building uses water for landscaping. The only audited building where water is used for landscaping is building 3200.

The Army Maneuver Support Center of Expertise (MSCOE) complex

The largest of the administrative buildings audited is actually a complex of four buildings connected and designated as the Maneuver Support Center of Excellence (MSCOE). Hoge Hall (3200) is the administrative and command side of the training center. It has 17 restrooms that have varying use rates depending on the adjacent offices and classes nearby. Hoge Hall is adjacent and connected to Lincoln Hall (3201) which has a dining facility and a coffee shop that caters to MSCOE occupants. Lincoln Hall was not audited. The Bruce C. Clarke Library (3203) was also not audited. Thurman Hall (3203) is the main classroom and training building within the MSCOE complex. Thurman Hall was partially audited, but the audit was not completed because of time constraints. Of the 27 restrooms in Thurman Hall, 14 were audited. Of the 17 restrooms in Hoge Hall, 9 were audited. Numbers of personnel working and students training were not available to the audit team. General observations from auditing done in Thurman and Hoge hall include:

- All the faucets were either 1.5, 2.0, or 2.2 gpm (Table 51). On average, they performed below rated flow. Regardless, they should be upgraded to 0.5 gpm to save water and thermal energy.

Table 51. Thurman and Hoge Hall average faucet performance.

Rated Faucet GPM	Avg Measured GPM	% of Rated GPM	# of faucets
1.5	1.05	70	9
2.0	1.57	79	31
2.2	1.36	62	29

- The men's urinal flushometer valves in Thurman Hall were all very slow to close, very difficult to flush and seem to have taken some abuse. The average estimated flush volume is 4.25 gpf. A water pressure test was not done, but it is likely these flushometers should be replaced with 1.25 gpf throughout the building.

MSCOE has its own irrigation system which has a rain sensor/evapotranspiration central control system. Witnesses said they have seen the system in use during rains so it is possible the system settings and sensors need to be reassessed.

Building 6100

The building is an administrative trainee company headquarters. It is a single story building built in 2012 with a combination of both offices and four training classrooms. During June and July, 2013, 4.5 kgal of water or 173 gpd were used based on recorded water meter data for 26 days. During the building's audit most of the offices space was in use, but not actively occupied. During the audit a couple of classes were conducted. It is likely that weekday restroom use occurs irregularly depending on the training schedule.

3.3.8.2 Commercial

Swimming Pools

Building 602 is an outdoor pool called Wallace Pool. It is a popular spot for families and has several water-related activities including two water slides, a children's pool, and an Olympic-sized pool with several lanes available for lap swimming. Based on daily logs, the average daily visitation is about 220 people over the pool's 8 to 9 hour weekend operation. Between the men's and women's locker rooms there are ten showers, ten toilets, and four urinals. Approximately 30% of attendees likely use the showers during their visits with an even mix of women to men using the facilities. Federal water use indices suggest every visitor to a recreational pool is likely to use about 10 gallons of water for hygienic purposes. This does not include the weekly pool flushing to clean the pool itself. Each pool flushing requires approximately 4,000 gallons of fresh water. The pool's highest occupancy is typically on the weekends, with lower attendance during weekdays (approximately 50 users). Total weekly attendance is estimated to be 700 people per week with a weekly demand of 7 kgal/week. Combined with weekly pool flushing, there is an estimated 11,000 gal/week demand or 28kgal/month, or 336 kgal/year.

Building 1300 is the Davis Recreational Center. The center is a large workout facility which hosts 2,500 to 3,000 people a day, every day of the week, using the pool for training along with the gymnasium, weight room, and exercise equipment. There are three sets of bathrooms along with two sets of locker rooms available to guests. The guest demographic is estimated to be 70% active duty males due to the training performed at the pool with the gymnasium used by spouses[*]. This building is not metered. Training conducted at this facility along with the regular gym likely requires 10 gallons per attendee. Additionally, trainees in full fatigues during drills carry a much larger amount of water out of the pool[†]. Throughout a rotation it is estimated that an additional 5 gallons per trainee are used or 80% of the total daily attendance[‡]. Combined, training and gym use may create a daily demand between 37.5 kgal and 45 kgal per day (13.7 to 16.4 MGY), but this is not verifiable until metered data are available.

Both pools are run by Morale, Welfare and Recreation (MWR), but they are maintained by the base contractor (TFW) who also manages the barracks. Contact with TFW had to be coordinated with the contracting representative and follow up information regarding their maintenance of the pools is forthcoming.

Toilets in building 1300 had an average measured flush volume of 4 gpf and urinals had an estimated average flush volume of 2.7 gpf. Due to the high use of these facilities it likely the flushometer valves on both the urinals and toilets need to be replaced. Actual water savings can be estimated if we assume each trainee and attendee uses the toilet or urinal only once while at the facilities due to their short facility use time. Possible regular toilet and urinal use would require up to 9.3Kgal/day (3.4 MGY)[§]. If the flush valves were replaced and met a rated capacity of 1.6 gpf per toilet and 1.0 gpf per urinal, the daily demand would then be 3.5 kgal, potentially saving 5.8 kgal/day (2.1 MGY).

885 Health Troop Clinic

The Health Troop Clinic (Bldg 885) contains three separate clinics. Laboratory personnel mentioned that all laboratory equipment cleaning and tests are sent to the hospital (Bldg 310). The clinic opens at 0600. Mornings are the busiest time because soldiers are required to report to sick call

[*] Assuming the 30% female demographic is made up of 10% active duty Soldiers and 20% female spouses.

[†] http://www1.eere.energy.gov/femp/program/waterefficiency_useindices.html

[‡] Adding 70% active duty male demographic and 10% active duty female demographic

[§] Assuming women demographics use only toilets and the male demographic uses only urinals using 3,000 daily attendance if they are unable to do PT. During the furlough, clinic hours were reduced by two hours in the afternoon.

1607 Museum

The museum (bldg 1607) contains one women's and one men's bathroom. During the audit, an officer's graduation was occurring. The bathrooms are available to all museum visitors, but are heavily used during graduations. Audits of the two bathrooms show that the toilets had extended flushes with an average flush rate of 4.6 gpf for 1.6 gpf rated toilets. The flow rates on the faucets were as low as 0.5 gpm for a 2.2 gpm rated faucet. No calcification was noted to inhibit flow, therefore both the low flow rates and extended flushes may be a result of low water pressure slowing the close of the diaphragm on the flushometer.

17480 Tactical Equipment Maintenance Facility

Although the TEMF building (17480) is large, water use is low. The building is equipped with 29 cold water stations which can be used with portable pressure washers. Based on discussions with soldiers assigned to the building, the pressure washers are only used about 1 or 2 times a month for a light spray down. Most vehicles are taken to the vehicle wash stations located elsewhere on the installation. Located in the building are two sets of women's and men's bathrooms with shower facilities. Personnel indicated that shower use in the building is infrequent. The female-to-male ratio for the building is 1 to 6. Soldiers also noted that the water from the water fountain tasted metallic. During the audit, it was observed that the wash fountain was used by soldiers to cool down equipment after welding.

3.3.9 Irrigation water use

Fort Leonard Wood has three large irrigated turf areas using potable water sprinkler systems. The areas include lawns surrounding the MSCOE complex, Gammon Parade Field, and two sport complexes of three fields each. In addition, Piney Valley Golf Course is irrigated with water drawn directly from the Big Piney River.

3.3.9.1 MSCOE

The turf ground surrounding MSCOE is irrigated using two different systems. The main irrigation system is a Rain Bird system. According to the installer's guidance, as the weather becomes hotter or dryer, the system water percentage or the frequency of irrigation should be set to increase in order to maintain green turf. The system operating at 100% uses a total of 86,280 GPD. However, this number does not reflect water use from manual irrigation, but only those areas irrigated by the automated irrigation system. Manual irrigation is used to water the north end of the building, along the breezeway, and at Building 3205. Figure 26 and Figure 27 indicate with red and yellow lines the areas that are irrigated using the Rain Bird system and by using manual irrigation, respectively. The total area irrigated by the Rain Bird system is approximately 8.38 acres. The total area manually irrigated is approximately 3.25 acres. In the spring, the practice of manually irrigating is done roughly three times a week with an 84 gallon tank. Shrubs and trees are also manually irrigated three times a week with a 500 gallon tank. The irrigation contractor is responsible for manual irrigation of shrubs and trees not just at MSCOE, but for the entire post.

Figure 26. Area irrigated by Rain Bird irrigation system marked in red.

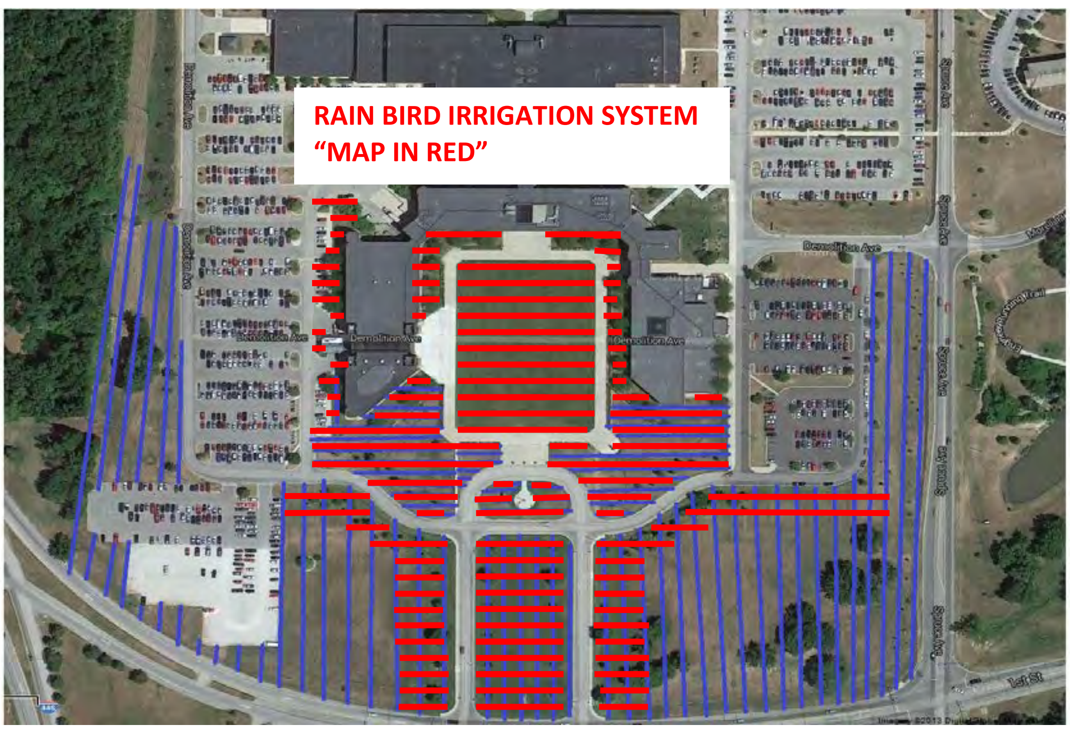
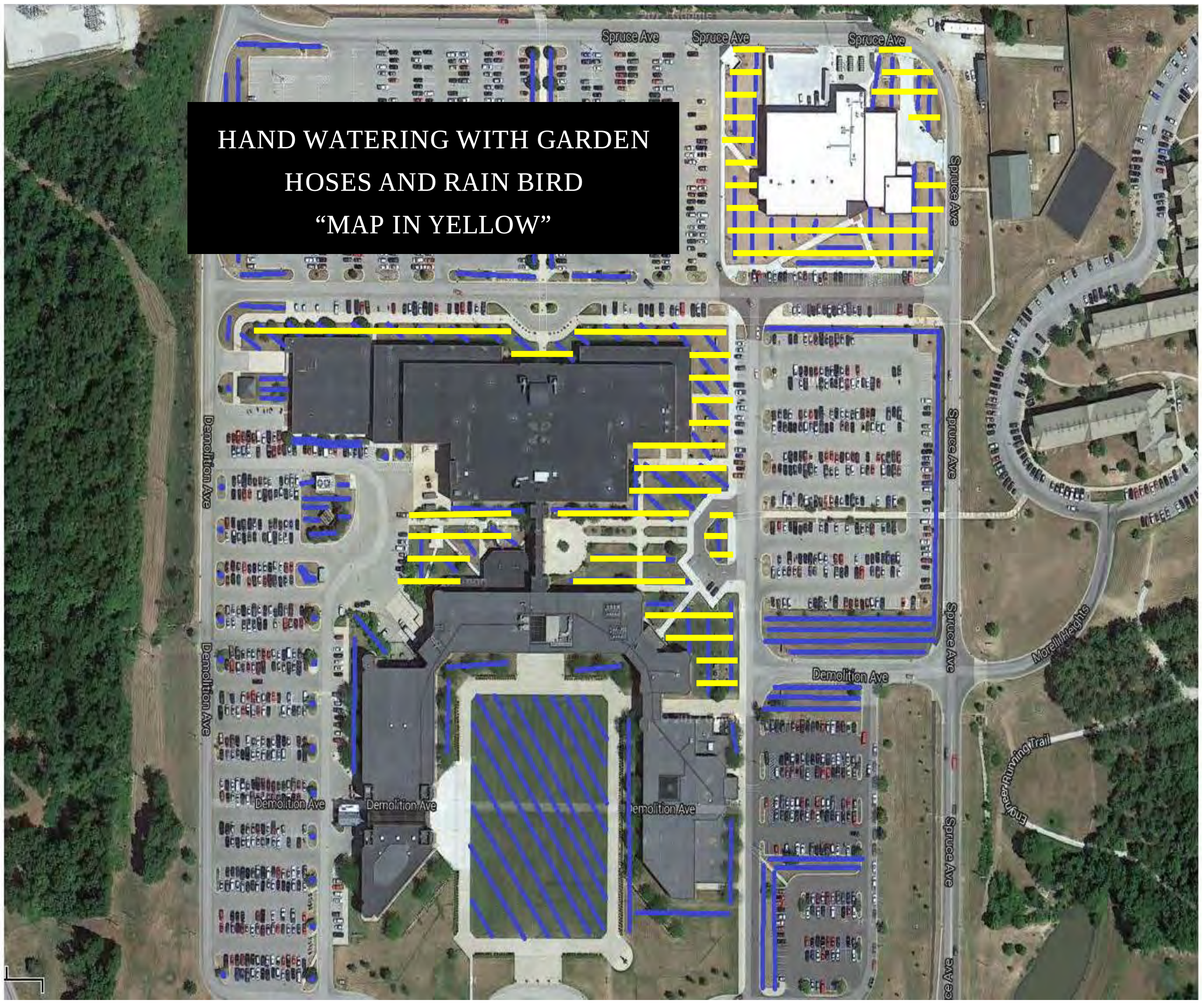


Figure 27. Area Irrigated by manual irrigation confirmed in YELLOW.



3.3.9.2 Sports fields

All of the sports fields on base are irrigated using a Rain Bird system. The sports fields are irrigated in 20 -25 min intervals for each set every night. There are a total of 15 all-turf fields that make up a total area of approximately 24.27 acres. It takes about 12 hours to irrigate the sports fields using current methods.

3.3.9.3 Parade field (Gammon Field)

Gammon field is also irrigated using a Rain Bird system and the total approximate area irrigated is 6.31 acres. Gammon Field has only turf, so different plant water needs are not considered. However, manual irrigation is also conducted but there is no meter system available to aid in tracking water use. Gammon Field is divided into eight zones. Zones 1-6 are irrigated for 1 hour and zones 7-8 are irrigated for only 45 min.

3.3.9.4 Piney Valley Golf Course

Piney Valley Golf Course is irrigated using a Rain Bird system (Figure 28). However, irrigation water is drawn directly from the neighboring Big Piney River. There is a significant leak at the pump where the water is withdrawn from the river. The volume of water leaking per day is unknown.

Figure 28. Rain Bird smart irrigation control system at Pine Valley Golf Course.

3.3.9.5 Residential Communities Initiative (RCI) Housing

The 168 housing units in The Woodlands housing area contain irrigation systems. There is no metered data for any housing units or neighborhoods so this value can only be estimated using typical irrigation ranges for off-post housing and estimated irrigated area. The area of turf for each housing unit is approximately 1830 SF for a total irrigated area of 7.06 acres. Figure 29 shows a RCI housing irrigations system in use.

Figure 29. RCI housing irrigation system.

3.3.10 Calculating water use

Two methods were used to calculate irrigation water use. The first is a general formula used in the landscaping industry to calculate the daily water requirement for irrigation in GPD. The values are then converted to gallons of water per week (gal/week) to enable comparisons to be made. The formula is as follows:

$$\frac{ETo * PF * SF * 0.62}{IE} = GPD$$

Where:

ETo = Evapotranspiration (volume of water needed for irrigation after evaporative losses. The value used here is **0.282** (Sanford and Selnick 2012).

PF = Plant factor (Use 1.0 for lawns/turf grass, 0.8 for water loving trees, 0.5 for average water loving trees, and 0.3 for low water loving trees (Rain Bird 2013). Because systems are operated at 100% not considering plant differences, a factor of **1.0** was used)

SF = Square feet of irrigated area

0.62 = conversion factor from inches of water to gallons of water

IE = Irrigation Efficiency (sprinklers have an IE of 50-75%, an efficiency value of 75% is used in the calculations)

To verify the usability of this method, the irrigation values provided by MSCOE were used as a baseline to compare to the calculated irrigation estimates. The value obtained from the Rain Bird system was 86,280 GPD.

Using the formula:

$$\frac{0.282 * 1.0 * 364{,}864.97 * 0.62}{0.75} = GPD$$

$$85{,}057.32 = GPD$$

$$1 - \frac{85{,}057.32\ GPD}{86{,}280\ GPD} = 1.42\%\ error$$

Comparing the results, the method used for calculating the amount of water needed for irrigation appears to be valid. Other irrigation locations can be estimated using the same method applied to the irrigated area.

The second method used to check this information was an AFCEE-developed water efficiency calculator (Isaacs 2012). The existing calculator was modified to include site-specific information for Fort Leonard Wood to estimate irrigation water use. Results from the two methods are compared in Table 52.

Table 52. Irrigation water use comparison.

Location	Area (acre)	Estimated Water Usage Baseline (GWD) From RainBird system	Estimated Water Usage per Day (GWD)	Estimated Water Usage per Week [GW/week (assuming 7days/week)]	Estimated Water Usage (Seasonal Usage Apr.-Sept. total of 183 days)
MSCOE (System Irr.)	8.38	86,280.00	85,057.33	595401.3016	15,565,491.17
MSCOE (Manual Irr. 3 Days)	3.25	-	33,014.45	231101.1808	6,041,645.16
Sports Fields	24.27	-	246,454.70	1725182.88	45,101,209.57
Gammon Field	6.31	-	64,108.00	448756	11,731,764.00
Residential Houses (168 at approx. 1830.03 sf/house)	7.06	-	71,671.59	501701.1141	13,115,900.55
		TOTAL	865,875.53	6061128.691	**91,556,010.45**
Golf Course (river water)	36.00	-	365,569.46	2558986.214	**66,899,211.03**

There is a significant amount of water on post that is unaccounted for when comparing annual potable water produced to sewage treated (Table 52). It is likely that some of the “missing” water is potable water used for landscape irrigation. A list of best management irrigation practices are recommended in order to minimize the use of potable water for irrigation (Annex 3-3, under Policy Changes).

3.3.11 Water meter flow recorder data

As part of the Fort Leonard Wood site assessment, the team installed portable flow recorders on the water meters of four buildings (Figure 30 and Table 53). A fifth building, 6100–Battalion Headquarters, also had a meter installed. However, technical errors prevented reliable readings for the first month of its installation.

Figure 30. Map of metered buildings with flow recorders monitoring water use.

Meter Master 100EL Flow Recorders were installed to monitor the water flow through fixed building water meters. The flow recorders can record up to 90 days of data when set at a one minute recording interval. The recorders have been used successfully on other projects (both at ERDC-CERL and other research labs) to develop building water use profiles. They provide both the absolute amount of water used during a time period and also identify time of day of use. Flow recorders can also point to unaccounted for water use.

Table 53. Buildings with flow recorders installed during June 2013 site assessment.

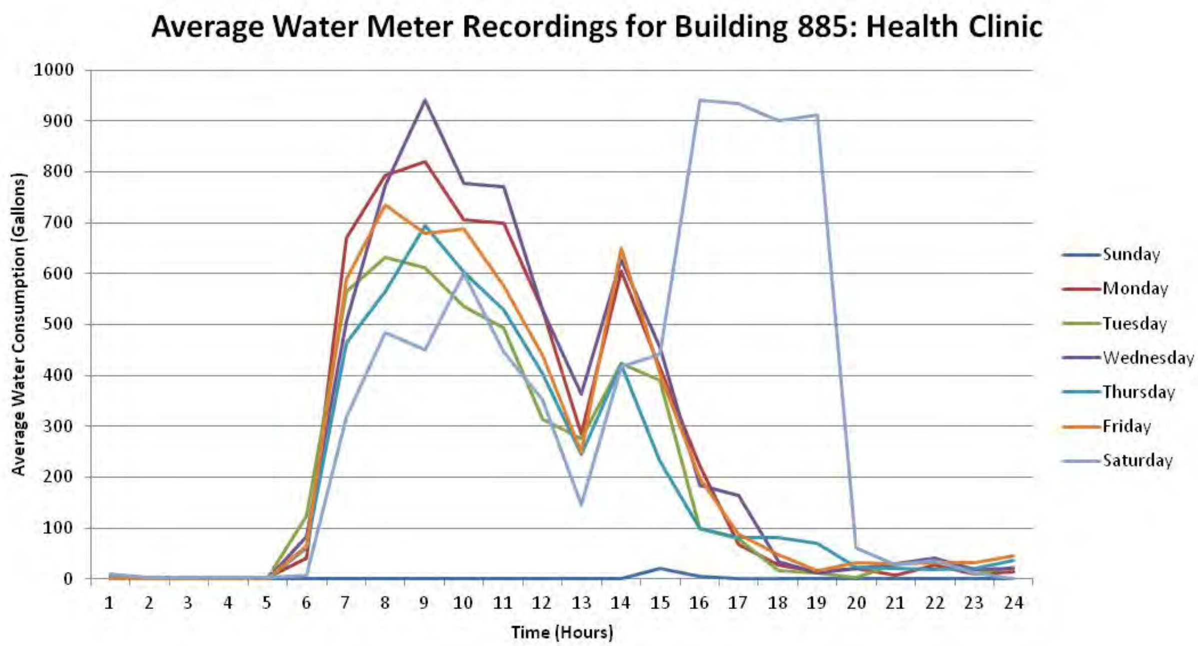
Building Number	Building Type	Meter Type	Flow Recorder Installed
6100	Battalion Headquarters	Badger	23 July 2013
6101	Trainee Barracks, AIT	Badger	June 2013
6102	Trainee Barracks, AIT	Badger	June 2013
4109	Consol. Open Dining, Pershing Club	Sensus	June 2013
885	Health Clinic	Water Specialties	June 2013

While logging is ongoing, the first month of data (June-July 2013) provided an interesting and rarely found high-resolution insight into water consumption habits in each of the five buildings. Four loggers—6100, 6101 4109, and 885—were set to record data at one minute intervals, whereas the logger on 6102 was set to record at 10 second intervals. Average hourly consumption for each of these buildings is presented in Figure 32 through Figure 35. It is important to note that data collection is ongoing and these results represent only a short time span during one summer.

Figure 31. Flow recorder installation at Bldg 6101, Barracks.

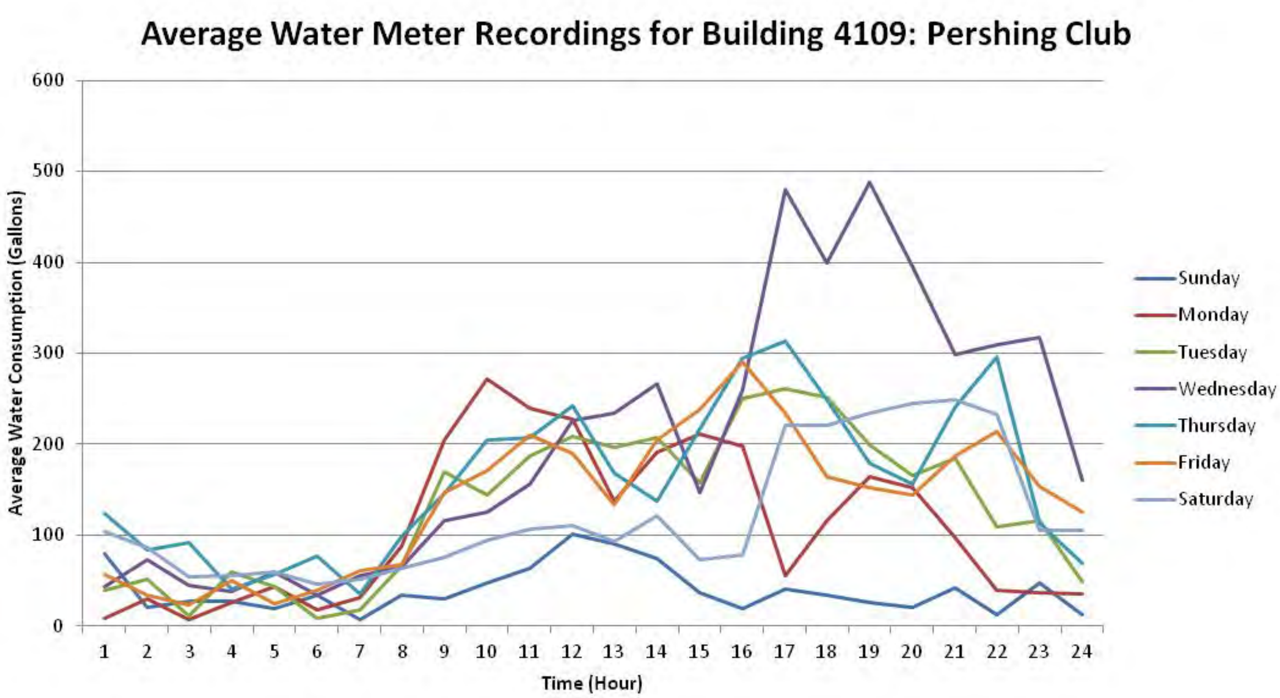
Building 885, (Figure 32) a troop clinic, has water consumption which is within the expected range given the clinic parameters discovered during personnel interviews. Water consumption is highest in the morning shortly after 0600, when soldiers report for sick call prior to PT. Another small spike in demand is observed after lunch. Clinic demand decreases dramatically after dinner. One exception requiring future evaluation is a consistently high water demand on Saturdays between 1500 and 1900, which may represent a process demand, such as irrigation or cleaning. On average, this demand rivals the peak demand of the peak day (0600 Wednesday) for total water consumption.

Figure 32. Data logger results for Building 885 during June-July 2013.



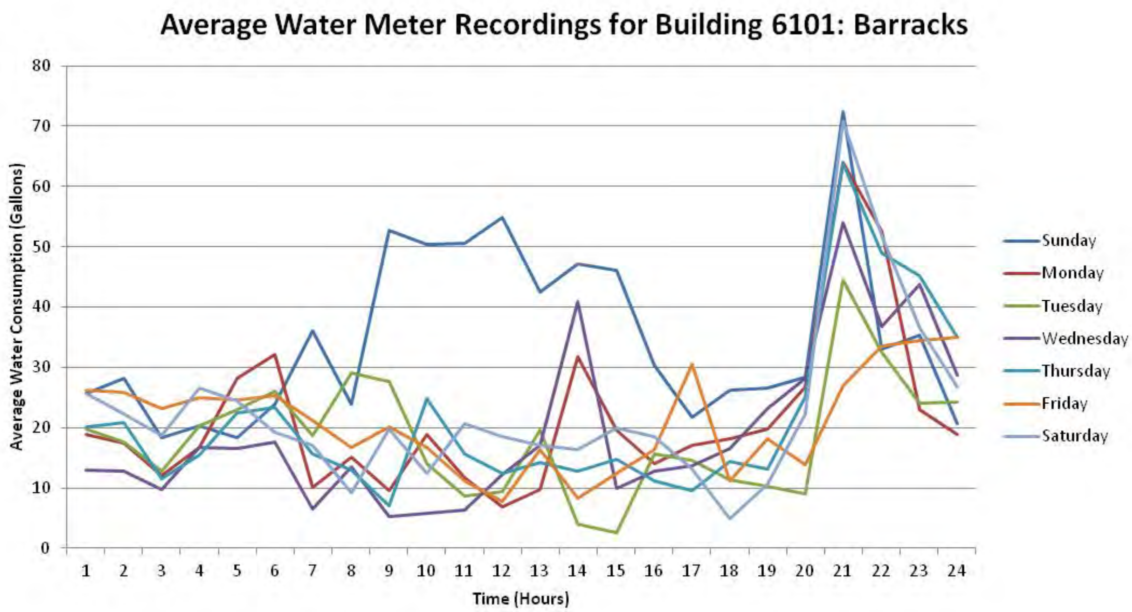
Building 4109- The Pershing Club, (Figure 33) has water use consistent with commercial kitchens having lunch and dinner service. The kitchen typically consumes approximately 300 gallons per hour during each business day, an amount consistent with similarly sized commercial kitchens. The largest consumption occurs on Wednesdays during dinner service.

Figure 33. Data Logger results for Building 4109 during June-July 2013.



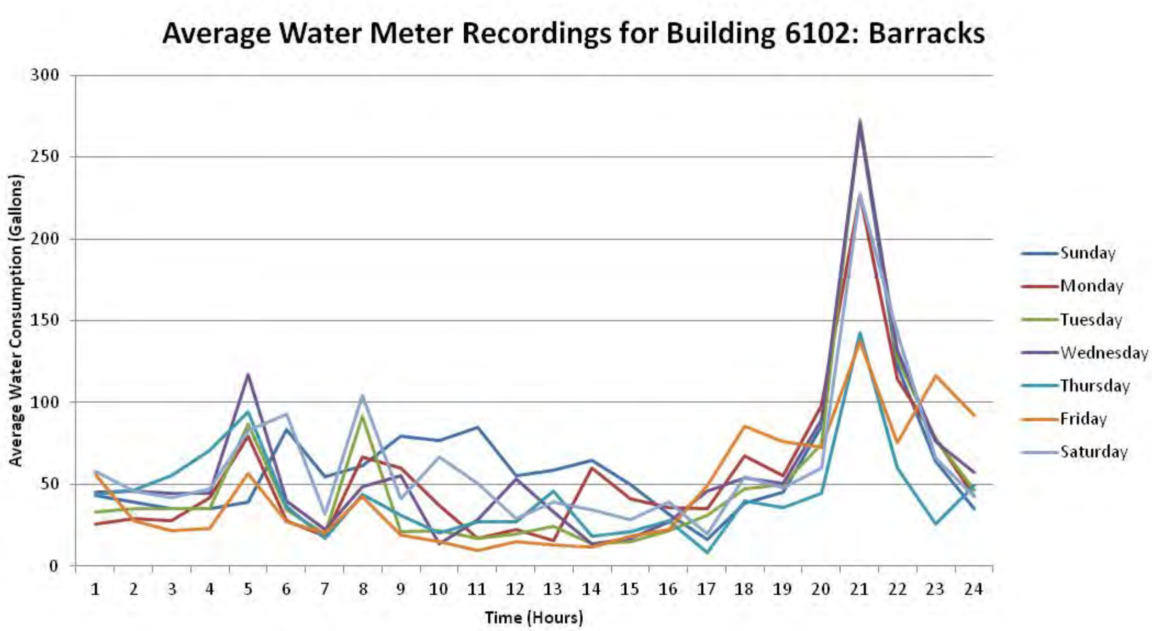
Building 6101 (Figure 34) is a large and relatively new barracks housing soldiers undergoing AIT. The low water use during this period may reflect less than full occupancy during the study period. A typical peak load is observed around 2100 nightly. This peak, observed elsewhere, (Figure 35) may represent nightly showers.

Figure 34. Data Logger results for Building 6101 during June-July 2013.



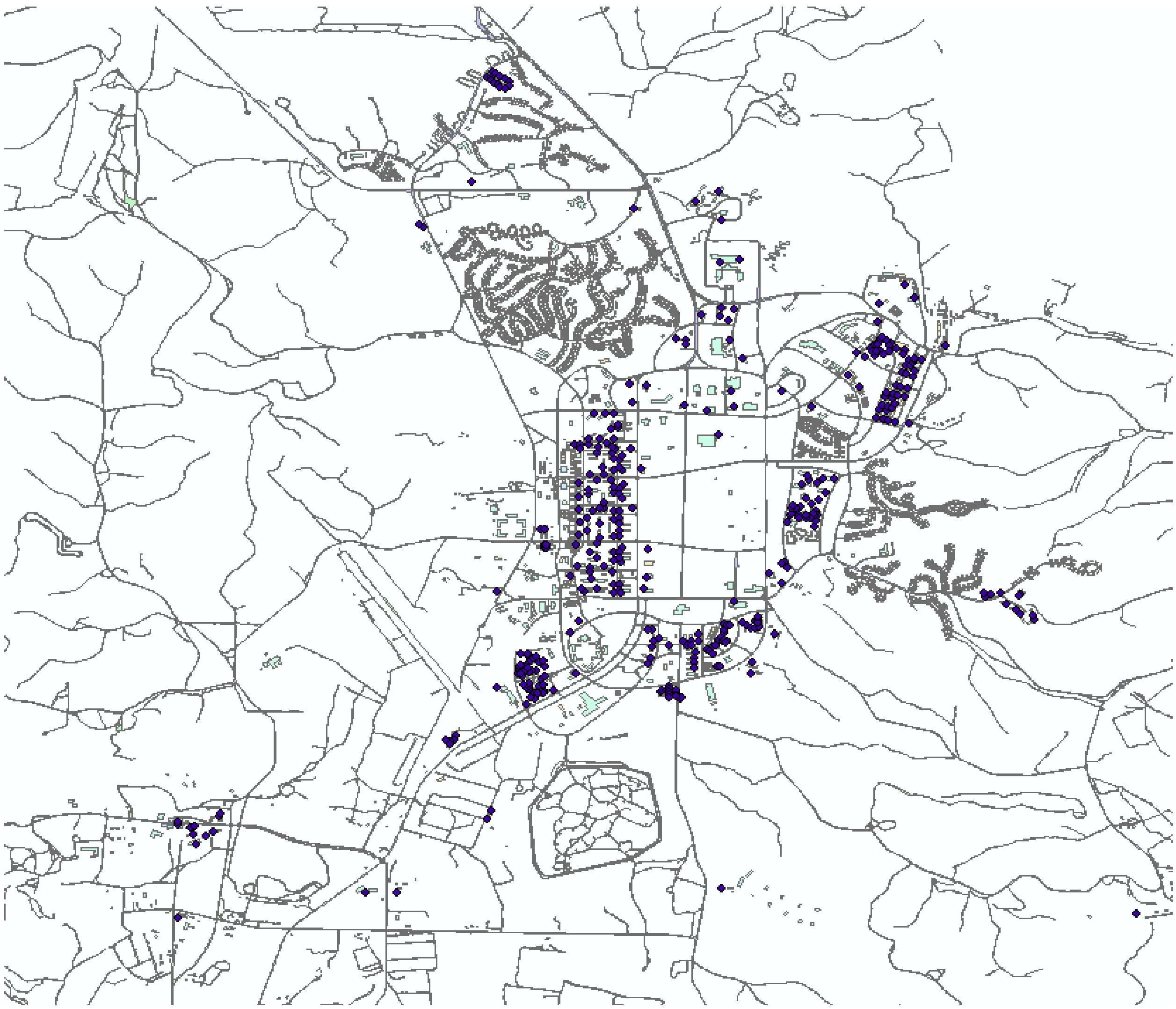
Another barracks- similar to 6101, but with a higher occupancy during the study period, is building 6102 (Figure 35). Physically (Figure 25), building 6102 is immediately adjacent to building 6101, and shares a similar demographic. While the magnitude observed is higher, the general shapes between the two demand profiles are consistent, with a large nightly peak around 2100.

Figure 35. Data Logger results for Building 6102 during June-July 2013.



In addition to the buildings currently being monitored, Fort Leonard Wood has a number of buildings either equipped with water meters or listed as capable of having such a meter installed (Figure 36). Recommendations will be made for additional meters to be installed for monitoring during the next phase of this project.

Figure 36. All buildings at Fort Leonard Wood listed as having- or capable of having- a water meter installed (represented by blue dot).*



3.3.12 Personnel interviews

Interviews with Fort Leonard Wood personnel were conducted during the June 2013 site assessment by one of the project teams. These interviews

* Contains barrel on which meter can be installed.

were the source of data and information that helped develop the water balance and identify water efficiency opportunities. The following is a brief summary of interviews.

1. Irrigation: Four irrigated locations on post were identified: MSCoE has a timer-controlled irrigation system that includes a rain gauge with some areas manually watered; Gammon Field parade ground irrigation system is set by the DWTP personnel; athletic field irrigation systems are set by FMWR staff; and, the golf course uses untreated water at the pump intake that is controlled with a smart irrigation system. One housing area is also irrigated and appears to be controlled individually by tenants.
2. Bulk water point. A bulk water point, with two dispensing hoses, is located at the airport. The potable nozzle is locked and controlled by the DOL to fill water buffalos. The non-potable nozzle is labeled as such because it is not controlled. it is available for the use of contractors, hydroseeders, and others.
3. Vehicle washing. The TA244 wash rack is located at the training area for construction equipment, dozers, backhoes, and other equipment. It contains several water cannons. 208/210 is a small wash rack.

Figure 37. Vehicle wash rack TA244.

1. Training water use: There are 28 live fire ranges, seven with water piped in. The last fire hydrant is at Range 18. There are 20 soldiers/training companies with an occupancy rate of 50% of trainees at the ranges. There is a summer surge which coincides with high school graduation. Special training water use includes:

    - TA250. Boat training facility with pond.
    - 250/Functional Academic Skills water training facility.
    - Bridge training site.
    - Skid pad.
    - Decontamination training. Pulls water from the pond for some of this; uses about 1 kgal/event, with approximately 20 classes/year taking place.
    - USACE quarry operations. Uses water to wash aggregate, but pumps directly from the Big Piney River and discharges to settling ponds.
    - There are several training areas that incorporate water use. These include the MP school's driver training course that includes a concrete water pit.

2. Pools/water parks. Building 602 (Wallace Pool) is an outdoor recreational pool, located at the RecPlex, that has two huge slides and a diving pool. It is backwashed twice weekly at about 5 kgal each time. Building 8220 (Leeber Pool) is an outdoor recreational pool not open to soldiers. It is older and may leak significantly as the 1 in. make-up line runs continuously. MWR estimate is 1,200 gpd. Balfour Beatty has three spray parks. Stone Gate, Building 1300, is an indoor pool used for soldier training. It is metered.
3. Fire hydrants: The fire hydrants are flushed once a year for five minutes each at 1400.
4. Dining facilities: Fort Leonard Wood has ten DFACS which are contract operated. TB Med 530 Sanitation Procedures establishes cleaning requirements which in turn influence water use.
5. RCI Housing: Balfour Beatty has a 50-year lease which started in 2008. There are 1,806 housing units with an average occupancy of 6,400/month. Water was billed at 120 gpcd until 2005 when this was reduced to 90 gpcd. The U.S. average for domestic water use is 98 gpcd (Kenny et al. 2009). There is no main meter for RCI neighborhoods. Some of the newer homes have individual meters though these have not been read historically. One newer housing area has 168 irrigated

lawns. Descriptions of neighborhoods are available at http://www.ftlwoodfamilyhousing.com/neighborhoods/ and listed in Table 54 below.

Table 54. Fort Leonard Wood neighborhoods that are managed by Balfour Beatty. (Balfour Beatty 2013).

Housing Area	Vintage	Assigned	Unit Types		
			2 BR	3 BR	4 BR
Eagle Point		E5 – E9		X	X
North Lieber Heights		E7			X
North Stonegate		E5 – E6		X	X
Piney Hills		E5 – E9, 01 – 010		X	X
South Lieber Heights		E1 – E6	X	X	X
Woodlands (168)*	2013	E5 – E6, 01 – 03		X	X

6. Privatized Army Lodging: Intercontinental Hotels Group (IHG) is the contract operator for guest lodging at Fort Leonard Wood. Lend Lease is the owner and IHG is the manager. There are 38 buildings ranging from cottages to a guest house for a total of 1653 rooms. Occupancy is measured in 'bed nights;' they average 40-45,000 bed nights/month. Meters have been installed, but are not read. IHG is billed for water based on a rate of 90 gpcd. Although they maintain 145 acres, there is no irrigation. Buildings that will be branded as Holiday Inn Express will use 'sunflower' showerheads.

* Woodlands neighborhood contains lawn irrigation systems.

Figure 38. “Sunflower” showerhead is the new design standard for privatized Army lodging quarters.

7. Drinking water system: The drinking water system contains four elevated water towers (500 Kgal each), a new 500 Kgal tank, and a ca. 1940s DWTP that still meets more stringent USEPA requirements. There is also a 400 gpm pump in a back-up well dug in the 1960s to a depth of 1050 ft. This provides 2-3% of annual water volume . Water from the well is used to fill a 2.25 MG ground storage tank which can be used to fight fires and as a back-up water source if the main pumps at the DWTP are unavailable. The DWTP is a GOCO. Water at the plant is metered before treatment and again before distribution. The difference should reflect DWTP process water (e.g., filter backwash). Average flow at the DWTP is 3.2 MGD or between 2.7 and 2.8 MGD. The six sand filters are backwashed every four days requiring 10 kgal each, for a total of about 100 kgal/week.
8. Wastewater Treatment Plant: The WWTP design capacity is 5 MGD and average annual inflow is 3 MGD. The largest inflow observed was 25 MGD due to storm inflow. Flow within the sewer system varies from 2,300 gpm to 13,000 gpm. Meter calibration may be one issue contributing to the delta between drinking water treated and wastewater processed.

3.4 Base Case: Projecting Fort Leonard Wood water demand 25 years out

The Base Case analysis assumes a business-as-usual scenario. All planned construction and demolition is incorporated as are any changes to Fort Leonard Wood's population.

3.4.1 Demand

Water consuming fixtures are assumed to be replaced at a series of attrition rates (depicted in the following tables) and to be replaced with fixtures meeting current Army requirements. As a first approximation of Base Case water demand, the 25 year period is broken into a series of five year snap shots. As shown in Table 55 to Table 59, future occupancies for Fort Leonard Wood were extrapolated from the projected change in building areas over the study period. This change in area and occupancy was further assigned linearly to each five year period, with conservative assumptions that, in general, water consumption per occupant per day will continue to trend downwards over the 25 year period as less efficient fixtures fail and are replaced with more efficient models.

Table 55. Base Case (Period One).

Base Case (2013-2018)				
Using Sector	**Gallons/ Day/ Occupant**	**Number of persons**	**Units**	**Total consumption (kGal/day)**
Family Housing[2]	98	12,136	Occupants	1,189
Barracks[1]	52	9,303	Occupants	484
Dependent Schools[1]	55	5,652	Occupants	311
Medical[3]	40	159.6	Occupants	6
Industrial and maintenance[1]	30	994	Occupants	30
Transient housing/ lodging/ UEPH[2]	48	3,112	Occupants	149
Administrative/ moderate users[1]	30	6,223	Occupants	187
Community and Commercial: non-food related (indoor)[1]	6	100	Occupants	1
Community and commercial (food-related)[1]	9	9,628	Occupants	87
Storage[1]	50	100	Occupants	5

Base Case (2013-2018)				
Total Daily Water Use in kGal				2,448
High Water Use Facilities				
Using Sector	**Quantity**	**Number**	**Units**	**Consumption (kGal/year)**
Irrigated/ improved land[1]			Acres	0
Fire hydrant flushing[2]	7	1081	kGal/hydrant	7,567
Training (pools, wash racks[2])	4,604	12	kGal/months	55,248
Losses[4]	0.1	956491.147	kGal	95,649
Total Water Use in kGal				**1,114,955**

Table 56. Base Case (Period Two).

Base Case (2018-2023)				
Using Sector	**Gallons/ Day/ Occupant**	**Number**	**Units**	**Consumption (kGal/day)**
Family housing[2]	95	12136	Occupants	1,153
Barracks[1]	50	10,104	Occupants	505
Dependent schools[1]	54	5,652	Occupants	305
Medical[3]	40	169.2	Occupants	7
Industrial and maintenance[1]	30	988	Occupants	30
Transient Housing/ lodging/ UEPH[2]	48	3,191	Occupants	153
Administrative/ moderate users[1]	28	6,257	Occupants	175
Community and commercial: Non-food related (indoor)[1]	6	100	Occupants	1
Community and commercial (food-related)[1]	8	10,093	Occupants	81
Storage[1]	50	100	Occupants	5
Total Daily Water Use in kGal				2,414
High Water Use Facilities				
Using Sector	**Quantity**	**Number**	**Units**	**Consumption (kGal/year)**
Irrigated/ improved land[1]			Acres	0
Fire hydrant flushing[2]	7	1081	kGal/Hydrant	7,567
Training (pools, wash racks[2])	4,604	12	kGal/Months	55,248

Losses[4]	0.1	944078.154	kGal	94,408
Total Annual Water Use in kGal				**1,101,301**

Table 57. Base Case (Period Three).

Base Case (2023-2028)				
Using Sector	**Gallons/ Day/ Occupant**	**Number**	**Units**	**Consumption (kGal/day)**
Family housing[2]	94	12136	Occupants	1,141
Barracks[1]	49	10,906	Occupants	534
Dependent schools[1]	54	5,652	Occupants	305
Medical[3]	40	178.8	Occupants	7
Industrial and maintenance[1]	30	981	Occupants	29
Transient housing/ lodging/ UEPH[2]	48	3,269	Occupants	157
Administrative/ moderate users[1]	28	6,291	Occupants	176
Community and commercial: non-food related (indoor)[1]	6	100	Occupants	1
Community and commercial (food-related)[1]	8	10,557	Occupants	84
Storage[1]	50	100	Occupants	5
Total Daily Water Use in kGal				2,440
High Water Use Facilities				
Using Sector	**Quantity**	**Number**	**Units**	**Consumption (kGal/year)**
Irrigated/ improved land[1]			Acres	0
Fire Hydrant flushing[2]	7	1081	kGal/Hydrant	7,567
Training (pools, wash racks, [2])	4,604	12	kGal/Months	55,248
Losses[4]	0.1	953454.639	kGal	95,345
Total Annual Water Use in kGal				**1,111,615**

Table 58. Base Case (Period Four).

Base Case (2028-2033)				
Using Sector	**Gallons/ Day/ Occupant**	**Number**	**Units**	**Consumption (kGal/day)**
Family housing[2]	92	12136	Occupants	1,117

Base Case (2028-2033)				
Barracks[1]	48	11,707	Occupants	562
Dependent schools[1]	53	5,652	Occupants	300
Medical[3]	40	188.4	Occupants	8
Industrial and maintenance[1]	30	975	Occupants	29
Transient housing/ lodging/ UEPH[2]	48	3,348	Occupants	161
Administrative/ moderate users[1]	28	6,325	Occupants	177
Community and commercial: non-food related (indoor)[1]	6	100	Occupants	1
Community and commercial (food-related)[1]	8	11,022	Occupants	88
Storage[1]	50	100	Occupants	5
Total Daily Water Use in kGal				2,446
High Water Use Facilities				
Using Sector	**Quantity**	**Number**	**Units**	**Consumption (kGal/year)**
Irrigated/ improved land[1]			Acres	0
Fire hydrant flushing[2]	7	1081	kGal/Hydrant	7,567
Training (pools, wash racks[2])	4,604	12	kGal/Months	55,248
Losses[4]	0.1	955753.336	kGal	95,575
Total Annual Water Use in kGal				**1,114,144**

Table 59. Base Case (Period Five)

Base Case (2033-2038)				
Using Sector	**Gallons/ Day/ Occupant**	**Number**	**Units**	**Consumption (kGal/day)**
Family housing[2]	90	12136	Occupants	1,092
Barracks[1]	47	12,509	Occupants	588
Dependent schools[1]	53	5,652	Occupants	300
Medical[3]	**40**	198	Occupants	8
Industrial and maintenance[1]	30	969	Occupants	29
Transient housing/ lodging/ UEPH[2]	48	3,427	Occupants	164

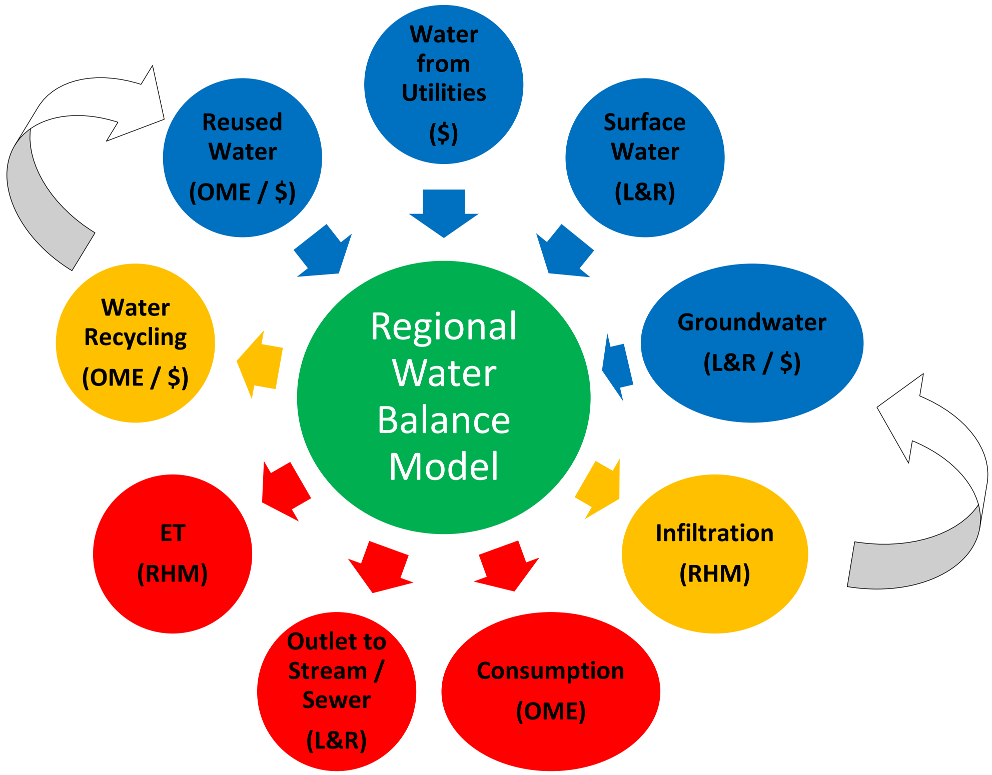
Base Case (2033-2038)				
Administrative/ moderate Users[1]	28	6,359	Occupants	178
Community and commercial: non-food related (indoor)[1]	6	100	Occupants	1
Community and commercial (food-related)[1]	7	11,487	Occupants	80
Storage[1]	50	100	Occupants	5
Total Daily Water Use in kGal				2,445
High Water Use Facilities				
Using Sector	**Quantity**	**Number**	**Units**	**Consumption (kGal/year)**
Irrigated/ improved land[1]			Acres	0
Fire hydrant flushing[2]	7	1081	kGal/Hydrant	7,567
Training (pools, wash racks[2])	4,604	12	kGal/Months	55,248
Losses[4]	0.1	955337.09	kGal	95,534
Total Annual Water Use in kGal				**1,113,686**

3.4.2 Supply

The evaluation of Fort Leonard Wood's water supply is partially complete. A separate ERDC effort analyzed the hydrologic ability of Fort Leonard Wood to sustainably provide for its water requirements from natural sources within the boundaries of the base. This was done by calculating the drainage areas of Roubidoux Creek and the Big Piney River from the post and comparing these values to historical stream gauge data. The Big Piney receives water from the local aquifer, increasing in water volume as it flows adjacent to Fort Leonard Wood near the eastern boundary, and through the post. Roubidoux Creek is an intermittent stream that runs on the western and northern boundaries of the post and both gains and looses water to the groundwater system. When taken together, sustainable use water available is between 36.0 and 78.4 $m*km^2$, whereas Fort Leonard Wood's potable water use is approximately 4.7 $m*km^2$ of water annually. Details of this analysis are contained in a report being prepared in ERDC format.

A regional water balance will be determined during the FY14 effort. The water balance provides an overall picture of supply and demand within the region of Fort Leonard Wood, identifying competing uses and describing how they may change over time.

Figure 39. Regional water balance model.



3.5 Alternatives

The alternative water use scenarios were developed based on findings from the site assessment and recommendations from Fort Leonard Wood personnel. Determining the effect of these scenarios on Fort Leonard Wood's future water demand will be calculated as part of the NZI assessment in progress. Calculations will use an assumed baseline from building water audits and a set of assumptions about planned water technology retrofits. The NZI outcome will include not only technology recommendations, but economic data to document life cycle cost parameters. Alternatives include a common set of retrofits and several alternate retrofits (Table 60).

Table 60. Fixture/equipment water efficiency standards.

Technology	Federal Law	Army Policy	WaterSense	Exceed WaterSense
Toilets	1.6 gpf max	SDD	1.28 gpf max	

Technology	Federal Law	Army Policy	WaterSense	Exceed WaterSense
Urinals	1.0 gpf max		0.5 gpf max	
Shower Heads	2.5 gpm max		2.0 gpm max	1.5 gpm
Faucets	2.0 gpm max		1.5 gpm max	0.5 gpm
Irrigation improvements				
Smart controls			Labeled	
High efficiency emitters				
System tuning				
PRSVs			Labelled	
Kitchen Appliances	Energy Star			FishNik

3.5.1 Alternative 1

- Replace failed fixtures with high efficiency fixtures: fixtures, kitchen appliances, PRSVs
- Irrigation system tune-up: inspect, adjust, replace as needed
- Policy revisions: incorporate best management practices, modify contracts, change SOPs
- Education/behavior program

3.5.2 Alternative 2

- Retrofit buildings (TBD) with high efficiency fixtures: showerheads and faucets/aerators

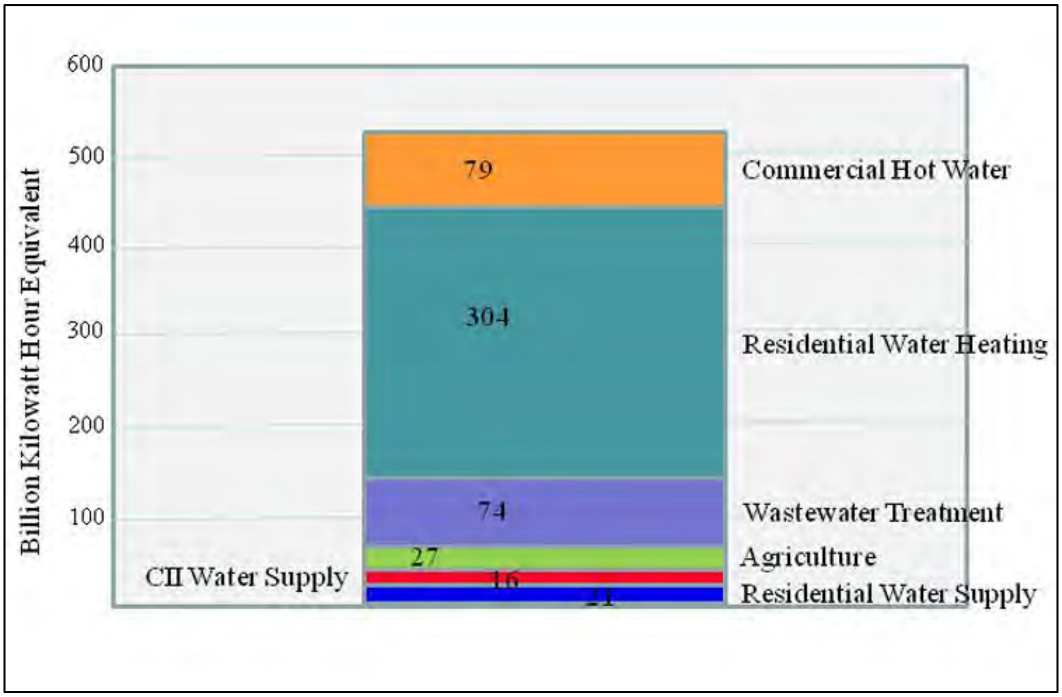
3.5.3 Alternative 3

- Leak detection audits

3.5.4 Water-energy interactions

Energy can account for 60 to 80% of water transportation and treatment costs and 14% of total water utility costs (Figure 40). Much of water resources development took place during the 20th century in an era of both low energy and water prices. Subsidized rural electricity increased agricultural production in irrigated areas and encouraged the use of irrigation in areas without direct access to surface water. Energy-related uses of water include thermoelectric cooling, hydropower, mineral extraction and mining, fuel production (fossil, non-fossil, and biofuels), and emission control. Energy demands in potable water systems include that required for pumping, transport, treatment, and desalination in addition to heating.

Figure 40. Embedded energy in the water use cycle, 2005.



(Griffiths-Sattenspiel and Wilson 2009)

The links between energy and water may seem problematic. However, there are several beneficial outcomes from addressing these resources together. Executing programs and projects that achieve both energy and water savings can support attainment of both program goals. Best use of resources is made when project funding can be used to reduce both energy and water consumption. Including energy savings in water projects will improve the project's economics, producing a shorter payback period, and a higher return on investment. Any time energy consumption is reduced, greenhouse gas (GHG) reduction follows, making water projects contributors to climate goals. Lastly, ignoring the water effects on energy or the energy effects on water may provide a solution to one resource problem while exacerbating other resource issues.

The water-energy interactions considered for this analysis are pumping energy required to treat and distribute potable water and the heating energy required within buildings. Embedded energy will drop with implementation of water conservation initiatives. These energy savings should be incorporated into the life cycle cost analyses (LCCAs) in order to improve project payback periods. Oftentimes, efficiency measures that reduce hot water consumption pay for themselves in energy savings alone. The methods for calculating embedded energy in water are shown below. The formulas are in Annex 3-2.

3.5.5 Water-waste interactions

Water use for a proposed concrete recycling facility. The facility should be sited close to a renewable water supply. For example, it should be adjacent to the existing quarry operation that uses non-potable water and possesses the required environmental permits.

Sludge is removed from the WWTP digestors which generates approximately 5% solids from an average of 21,000 gal/day that are treated. The sludge is sprayed on multiple closed landfill sites. There is a regulatory limit of two dry tons/acre-yr.

Figure 41. Biosolids management area.

3.6 Water planning conclusions and recommendations

3.6.1 Comparison of alternatives

Alternative comparison will be a future step in the NZI assessment of Fort Leonard Wood. The Net Zero Planner is being modified to integrate water and waste with the current energy analysis capability. The capabilities of the NZP tool will allow such comparisons to be completed quickly and consistently. This section will include visuals that show the difference in water/energy savings and investment cost for each alternative. Table 61 shows a sample of the type of analysis that could be accomplished using a future version of the Net Zero Planner.

Table 61. Comparison of water and cost savings between alternatives.

	Cost Svgs	Water Savings (gal)		Water Savings (%)		CO2 Reduction
Alternative	($/year)	Source	Site	Source	Site	(%)
Base Case						
Baseline						

Alternative 1						
Alternative 2						
Alternative 3						

3.7 Recommendations

3.7.1 General recommendations

Irrigation efficiency improvements: distribution, spray heads, controls, grass type, use of xeriscaping, landscape design, use of alternative water sources, such as reclaimed water.

Reduce freshwater use (e.g., direct withdrawals from wells and the Big Piney River).

Add certified advanced meters which send data to the Meter Data Management System for billing of reimbursable customers; calibrate existing DWTP and WWTP meters.

Hot water heating temperatures should be consistent, safe, and just high enough to do the job, but not promote biological contaminates. Investigate the use of solar power which is a 30% requirement.

RCI/PAL Billing: recommend using certified advanced metering and modifying the contract with RCI housing/Privatized Army Lodging. Can this be done at the installation or at headquarters (IMCOM/HQDA)?

Contracts: investigate the applicability of mandated water efficiency standards for tenants and contractors. These standards should be referenced in all contracts.

Provide water conservation training for incoming units during their safety in-brief.

A base-wide Water Conservation Awareness Program would be beneficial to encourage people to reduce their water use and report leaky fixtures to maintenance staff.

3.7.2 Building-specific recommendations

Programmatic upgrades across every building type should focus on high efficiency fixture installation through replacement of older equipment. The systematic upgrade should focus on contractor installed 1.28 gpf flushometers, 1.5 gpm showerheads, and 0.5 gpm bathroom faucet aerators. Showerheads and aerators should be installed immediately since a favorable economic payback can easily be achieved when including both energy and water in the life cycle cost assessment. Flushometers should be phased in during every building upgrade or remodeling. Zurn high efficiency products seemed to perform as rated and older Sloan equipment did not. In new residential housing, contract language should require high efficiency fixtures and appliances if it does not already.

Barracks: Older barracks on average had water temperature settings much higher than newer remodeled barracks and they should be reset to save energy.

Administrative: During auditing of the largest administrative building, MSCOE, the audit showed that urinal flushometers require maintenance and should be upgraded to 0.125 gpf when they need to be replaced. Observations of the automated irrigation system of MSCOE also suggest that the program and equipment needs to be evaluated to verify it is performing efficiently.

Dining Facilities: Leaking pre-rinse spray valves were observed at every dining facility. This equipment can both save and lose an incredible amount of water and energy for each dining facility. Comments from facility managers suggest the process to replace them is prohibitive. Therefore, the acquisition process to purchase new equipment for DFACs should be reviewed in order to keep equipment functioning properly. Upgrades to DFAC wash basin aerators should be part of the overall systematic faucet upgrades throughout the installation.

Recreational: Water demand at MWR facilities is difficult to capture accurately, especially at high use facilities such as Building 1300. It is recommended that Building 1300 and each outdoor pool have water meters installed to capture the actual demand.

Irrigation: Irrigated areas throughout Fort Leonard Wood need to be comprehensively documented and their management coordinated. This will ensure that each watering event is optimally performed during the day. A centrally controlled system with rain sensors should also be installed. The water savings possible through conservative irrigation is underestimated and should be explored further. In addition, shifting from using freshwater to alternative water should be considered to support the new reporting requirements for industrial, landscape and agricultural (ILA) water savings.

3.7.3 Recommendations from Fort Leonard Wood staff

- Meter high-volume water users.
- Assess irrigation control systems to determine if they can be more efficient in their water use, including the installation of climate-based controllers, where appropriate.
- Recycle wash rack water; use alternative water for any make-up water.
- Replace chiller water piping in 1,700 area, to prevent loss of 12,000-13,000 gallons per day.
- Audit buildings to assure toilets/urinals have appropriate flush rates.
- Replace piping: West main: 24 in. water main from plant to 4th Street tank, South main: 24 in. water main from west main to airport tank, North Main: 24 in. water main from plant to the Gas Street tank.
- Develop/update comprehensive water system model.
- Develop/update comprehensive fire flow study.
- Review annual hydrant and valve exercise programs (Elseman 2013).

3.8 Status of ongoing water efforts (FY14)

Determine water availability for post by GW and SW sources: Surface water hydrological model was created and details of this analysis are contained in a report being prepared in ERDC format. Regional water balance model has been written and is being 'translated' for use with the Net Zero Planner.

Characterize water usage patterns by end use; purchase and install meters at key locations and use flow recorders to establish use profiles: Flow recorders have been installed since June 2013, with data downloads at 3-month intervals. Locations for installed water meters will be made this year, with a focus on reimbursable customers and high water uses.

What is the energy cost of water use and how do we do it better: Work has reviewed the water pricing calculation including energy cost of pumping water. Further investigation will document factors (energy and other costs) that, while they contribute to Fort Leonard Wood's cost to produce water, are not billable to customers nor included in AEWRS-reported water cost.

How do we do it better: A water technology guide is being developed to provide brief technology descriptions along with recommendations for applicability by facility type. Current law, policy and guidance is being compiled in a concise manner so that it can be included as a reference in contracts (e.g. maintenance, retrofit, construction) and be readily accessed and referenced by DPW personnel.

3.9 Recommendations for continued water efforts (FY15)

- Continue characterization of water usage patterns. Additional building water meters have been identified; flow recorders will be used to document water use in a variety of buildings and also of any new water meters that are installed.
- Develop a projection of water main replacement investment using the American Water Works Association's *Buried No Longer Pipe Replacement Modeling Tool*. Required inputs are inventory of potable water distribution system by size and material, age, history of breaks/repairs, and soil type.
- Conduct a water quality assessment using field water chemistry kits. Inventory existing water softeners and identify operating parameters with the intent of determining the amount of water required to soften water at Fort Leonard Wood (water is required to backflush softeners).

Annex 3-1: Water system description

The Fort Leonard Wood potable water system is government-owned and self-contained within the post. The potable water source is the Big Piney River which runs along the eastern edge of the post. The intake for the river consists of a low-head dam with spillway, an intake screen, raw water suction, and raw water pump house. The pump house has four electric pumps (two 2.5 MGD pumps and two 4 MGD pumps) and a 2.5 MGD diesel engine backup pump. The raw water intake sends water through two 16 in. mains to the drinking water treatment plant (CEWMP 2011). It also has a 2.25 MG ground storage tank (Pendleton and Elseman 2013).

The Indiana well provides approximately 2.5% of the potable water supply. This well has three 400 GPM pumps and a 2.25 MGAL ground storage tank. The Indiana well is tied directly into the distribution system for the cantonment. There are 13 small satellite wells that are capable of providing support for remote areas and small clusters of buildings that includes training ranges (CEWMP 2011). The wells are treated with on-site chlorination. The last fire hydrant for range support is located at Range 18 (Campbell 2013).

Other sources of water for the post include untreated Big Piney River water used to irrigate the golf course and for quarry operations.

The water distribution system primarily consists of cast iron from the 1940s, with later system extensions of cast iron, ductile iron, and polyvinyl chloride (PVC). The system includes 1,081 fire hydrants and four 500,000 gallon storage tank, a 2.25 MG tank associated with the Indiana well, and a new tank that supports the water line extension to the ranges (CEWMP 2010).

The Fort Leonard Wood water distribution system is one large pressure zone. This presents a challenge in addressing systemic issues such as leak detection in just one part of the system.

The CERL team evaluated the building water metering program at Fort Leonard Wood. DPW staff initially identified fourteen buildings that contained building-level water meters, comprised mostly of reimbursable customers. Although meters are not required for reimbursable customers, they provide greater accuracy than estimated bills. CERL researchers find that water use estimates are often lower than actual measured use.

Additional information provided by the DPW included a list of buildings constructed after 1990 that should be physically configured to accept a water meter. Yet another source of water meter information was a list of LEED-certifiable buildings that were expected to contain water meters due to the requirements of this Green Building Council (GBC) program. However, it was later found, through a site audit, that most of these buildings did not have water meters.

Follow-on water meter work will include recommendations for locations to install water meters for optimum benefit for reimbursement by tenants and to monitor the distribution system for leaks and losses.

The DWTP has a capacity of 5 MGD with a reported average daily treatment rate of 2.6 – 2.8 MGD (CEWMP 2011). Additional research by the audit team discovered a range of values reported by DPW staff as well as a metered range of from 1.025 to 3.976 MGD between 2000 and 2013, based on monthly totals (FLW 2013).

The WWTP design capacity is 5 MGD and average annual inflow is 3 MGD (Fort Leonard Wood site visit outbrief). The largest inflow observed by the interviewed operator is 25 MGD due to storm inflow. Flow within the sewer system ranges from 2,300 gpm to 13,000 gpm. Meter calibration may be one issue contributing to the delta between drinking water treated and wastewater processed.

The CEWMP identifies old infrastructure, lack of meters, and lack of controls as weaknesses of the potable water infrastructure. Water loss was stated to be unknown at the time, although smoke tests of the sewage system have been carried out. Other planning tools and audits include an Infrastructure Capacity Analysis (2009), Water Management Plan (2005), and Installation Water Contingency Plan (2005) (CEWMP 2011).

Annex 3-2: Water-energy calculations

Total Energy Consumption Calculation

Water Heater Energy Calculation

$$Energy\ Consumption = \frac{Q_{hotwater} * \rho_{water} * C_p * (T_{set} - T_{supply})}{RE} * \left[1 - \frac{UA * (T_{set} - T_{air})}{P_{on}}\right] + 24 * UA * (T_{set} - T_{air})$$

where:

$$E = Energy\ Consumption\ [\frac{kW}{day}]$$
$$Q_{hotwater} = Volume\ of\ Hotwater\ Consumption\ \left[\frac{m^3}{day}\right]$$
$$\rho_{water} = Density\ of\ Water\ \left[\frac{kg}{m^3}\right] = 1000$$
$$C_p = Specific\ Heat\ of\ Water\ \left[\frac{kWh}{kg*°C}\right] = 0.00116277778$$
$$T_{set} = Thermostat\ setpoint\ temperature\ [°C]$$
$$T_{supply} = Water\ supply\ temperature\ [°C]$$
$$T_{air} = Ambient\ air\ temperature\ [°C]$$

$$RE = Recovery\ Efficiency = 0.76\ (fuel\ type: natureal\ gas)$$
$$P_{on} = Rated\ input\ power\ [kW]$$
$$= 11.723(fuel\ type: natureal\ gas)$$
$$UA = Standby\ heat\ loss\ coefficent\ \left[\frac{kW}{°C}\right]$$
$$UA = \frac{\frac{1}{EF} - \frac{1}{RE}}{(T_{tank} - T_{air}) * \left(\frac{24}{113.0051} - \frac{1}{RE * P_{on}}\right)}$$
$$T_{tank} = Water\ heater\ Tank\ actual\ temperature[°C]$$
$$EF = Energy\ Factor$$
$$= 0.48\ (fuel\ type: natureal\ gas, pre\ 1985)$$

Water Heater Analysis Model (WHAM) was used to calculate the energy consumption used by the water heater equation developed by Lawrence Berkeley National Laboratory (Kelso 2003). The WHAM equation calculates in English units therefore needs to be converted to SI units for calculations wanting an SI unit. The simplified equation requires several parameters for the energy consumption estimation. The daily draw of total hot water volume is calculated within the model accounting for the number of water fixtures that use hot water. General parameters such as water density, specific water heat were given a constant value while other parameters such as RE, EF, Pon, and UA were values based on water heater fuel type and whether the water heater is post or pre-1900. The equation uses both the actual water heater tank water temperature and the water heater set temperature for the estimation. These two values should be very close to one another, if not the same.

Pump Energy Calculation

$$P = \frac{Q * H}{3960 * \eta} * \frac{0.746\ kW}{HP} * \frac{18\ hours}{Day}$$

where:

$$P = Power[kW/day]$$
$$Q = Pumping\ Rate\ [GPM] = 6597$$
$$H = Average\ head\ plus\ friction\ [ft] = 450$$
$$\eta = Efficency = 0.65$$

The pump Energy calculation was provided from the 2013 Fort Leonard Wood Utility Cost report for water. The calculation includes conversion from horsepower to kilowatt and assumes the pump usage of 18 hours a day.

Total Energy Consumption = Water Heater Energy Consumption + Pump Energy Consumption

Finally, the total energy consumption used to pump and heat the water is the sum of energy used in the water heater and the energy used to pump the water.

Annex 3-3: Description of water efficiency measures

Policy changes

Maintenance contracts

Specify efficiency of replacement fixtures. Check hot water temperatures.

Reimbursable customer billing

Install meters for all reimbursable customers for billing purposes.

Bulk water point

Control usage. Consider automated dispensing system.

Irrigation best management practices

The first recommendation involves zoning. At the present time, there is only one area, Gammon Field that is zoned. However, speaking with other representatives on site, there is currently no zoning practices for any of the other areas. This is a simple yet a very effective strategy to save water because it takes into consideration the different amount of water required for different plant types, when applicable. Considering how much water different plant types desire and zoning according to this factor will help in reducing water usage on plants that do not require as much water as others. Currently, there is no zoning reported for this purpose. All plants and surfaces are watered the same. Providing too much water could kill those plants that do not require as much water. If this takes place, there would be an added cost to purchase plants to replace the lost ones. This is a cost that can be avoided by considering zoning strategies and taking account of the various plant types in the irrigated zone. In addition, it would prove beneficial to verify that throughout the prescribed zone, water is being distributed evenly. Various techniques exists that can be used to determine whether or not even distribution of water throughout the zone is taking place. Depending on soil and other factors, it is estimated that approximately 2 inches of water should be evenly distributed throughout a prescribed zone.

Effective scheduling is also very important. In some cases, too much water is allocated to a space and the soil does not have enough time to absorb it. Consequently the water just runs off to sidewalks, streets, or neighboring buildings. Of course, in hotter periods of the year, some of the water evaporates before the soil has a chance to absorb it but this is when proper planning for time of day irrigation is crucial. At the present time, though there might be an irrigation schedule, it was communicated that irrigation in many cases takes place at the authoritative body's own discretion. If sprinkler heads and their respective locations were adjusted so that water is only being delivered to the desired area and only to those objects that actually grow, significant water savings could be realized. For example, if sprinklers are watering sidewalks, then it is not effectively placed in a location that is optimum for water use and should be considered for relocation. Also, when temperatures and winds are too high, causing a loss of water, a good approach would be to adjust the sprinkler head water distribution mode so that heavier water droplets are delivered rather than the more misty type of delivery typically seen. Adjusting the sprinkler head to deliver heavier water droplets, it makes it more difficult for evaporation and redistribution due to wind to take place. Intermittent irrigation and proper time of day irrigation could be useful in addressing this problem as well.

Another effective form of irrigation to save water is drip irrigation, also called micro-irrigation or trickle irrigation. Drip irrigation focuses on watering the roots of plants or turf grass and consequently minimizes or completely eliminates the watering of non-target areas such as roads, sidewalks, tree trunks, buildings etc. Drip irrigation systems are rated to have an efficiency as high as 90% compared to sprinklers which are around 30%-75% efficient at best. Because water is being applied directly to the roots, it allows plants, grass, and trees to use the applied water more effectively, eliminating the possibility of evaporation. In addition, because water is being applied in a controlled, systematic fashion, issues with run-off are also avoided. By minimizing water contact in areas that it is not needed, this is an effective way to restrict weed growth, reduce costs for chemicals, maintenance, and all other expenses related to weed control. It is very important to select the proper system for the space one would wishes to irrigate using this method. Professional assistance should be used to achieve optimum results. Since a large portion of the sprinkler systems on base are provided and installed by RainBird, it is recommended that the considering parties seek their assistance in finding the best solutions to meet their goal. There are many residential areas on base that are not metered and it is almost impossible to acquire any data on their water usage. This system could help monitor residential water use and minimize a large portion of the water waste. Rain Bird does provide and professionally install drip irrigation systems.

Annex 3-4: Behavior/educational programs

Awareness

A water awareness program will strive to reach every person on the installation. All available media will be used including news outlets, signage, and a "hotline" for waste reporting. A building water monitor program can provide eyes and ears on the ground. Recognition programs are key to success. Awareness programs offer opportunities for partnering as can be seen with Fort Huachuca's Water Wise and Energy Smart Program (WWES). This program includes conservation, public outreach, youth education, water use audits, conservation tips, and information about landscaping (University of Arizona 2011).

Education

A formal water management education program is necessary to inform all who affect installation water use, which is everyone who lives, works on, or visits an installation. The program should target each specific audience:

- soldiers,
- DPW/contractors,
- family members, and
- visitors.

Special training should be provided for maintenance staff and for building water monitors.

Behavior Programs

The Office of the Assistant Secretary of the Army for Installations, Energy and the Environment (ASA(IE&E)) is working with the Environmental Protection Agency under their Net Zero Installations Memorandum of Understanding to explore the effect of conservation awareness programs on water use behavior. This project includes reading individual RCI housing water meters and comparing the water behaviors, as reflected in the monthly metered use, between individuals who have received water conservation material and those who have not. The results of this project will be disseminated and should be incorporated into broader water conservation behavior programs at Fort Leonard Wood.

4 Net Zero Solid Waste

This chapter was authored by Stephen D. Cosper, Thomas R. Napier, Dick L. Gebhart, and Giselle Rodriguez of ERDC-CERL.

The ERDC-CERL team has studied Fort Leonard Wood solid waste disposal issues and developed tools to help installation management personnel make decisions that align with government regulations, Army mandates, and Fort Leonard Wood Net Zero goals.

Before engaging in the details, it is useful to clarify some nomenclature:

- *Demolition:* Demolition is the tearing down of buildings and other structures. Demolition contrasts with deconstruction which involves taking apart while carefully preserving valuable elements for re-use.
- *Deconstruction:* In the context of physical construction, deconstruction is the selective dismantlement of building components, specifically for re-use, recycling, and waste management. It differs from demolition where a site is cleared of its building by the most expedient means. Deconstruction has also been defined as "construction in reverse". The process of dismantling structures is an ancient activity that has been revived by the growing field of sustainable, green method of building. Buildings, like everything, have a life cycle. Deconstruction focuses on giving the materials within a building a new life once the building as a whole can no longer continue. Deconstruction is a method of harvesting what is commonly considered "waste" and reclaiming it into useful building material.
- *Recycling:* Recycling is a process to change materials (waste) into new products to prevent waste of potentially useful materials, reduce the consumption of fresh raw materials, reduce energy usage, reduce air pollution (from incineration) and water pollution (from landfilling) by reducing the need for "conventional" waste disposal, and lower greenhouse gas emissions as compared to plastic production. Recycling is a key component of modern waste reduction and is the third component of the : "Reduce, Reuse, Recycle" waste hierarchy.
- *Municipal Solid Waste (MSW):* typically refers to solid wastes that are routinely generated from the daily operation of a given municipality. In this document, the term "MSW" is defined as household wastes and

wastes from business and commercial office activities. Excluded from this definition are mining wastes, construction and demolition wastes, hazardous wastes, industrial and manufacturing wastes, wastes associated with training, and commercial vehicular wastes.

- *Waste Diversion:* The term "waste diversion" refers to the reduction in the amount of wastes that are disposed. This includes both reducing the amount of waste generated in the first place, and recycling and reusing the waste product. Waste to energy (WTE) is a form of disposal in which energy is recovered from the wastes. Similarly, other waste treatments produce beneficial products from waste, i.e., composting and anaerobic digestion, which recover nutrients from the processed waste stream. "Disposal" refers to the final disposition of wastes that cannot otherwise be recycled or reused.

The generation of and responsibility for MSW and construction and debris (C&D) are usually different groups on the installation. DPW has responsibility for MSW collection. Whereas, for major projects USACE contractors generate, and must dispose of C&D. Therefore, for the purposes of this document MSW and C&D will be addressed separately.

Residential areas (family housing) at military installations are generally operated by a contractor via the residential communities initiative (RCI) program. There is no SWAR data available for family housing in Fort Leonard Wood after 2005. Therefore, we have excluded this portion of the stream from our study. Residential areas are likely to be similar to national averages in waste generation. One key difference between military housing and the average civilian neighborhood is the higher rate of turnover due to relocation at military residential area. When a residence is vacated, a large amount of waste is typically generated as residents want to dispose of unneeded clothes, electronics, furniture, household items, food, etc. Managing these departures will be critical in reducing wastes in these areas. (Medina, Wynter, Waisner, Cosper, and Rodriguuez 2013).

Construction and Demolition (C&D) debris constitutes over half of the Army's non hazardous solid waste stream, as documented in FY 12's SWAR system. This figure was as high as 67% Army-wide, and 80% at some Army installations, at the height of MILCON transformation. Reducing this burden can contribute significantly to installations' net zero solid waste goals.

4.1 Goals and requirements

4.1.1 Executive Orders

Federal solid waste management standards are captured in the following executive orders:

Executive Order 13423 (January 2007) - Strengthening Federal Environmental, Energy, and Transportation Management

"(e) Ensure that the agency:

(i) reduces the quantity of toxic and hazardous chemicals and materials acquired, used, or disposed of by the agency

(ii) increases diversion of solid waste as appropriate, and

(iii) maintains cost effective waste prevention and recycling programs in its facilities"

Executive Order 13514 (October 2009) - Federal Leadership in Environmental, Energy, and Economic Performance

"(e) Promote pollution prevention and eliminate waste by:

(i) minimizing the generation of waste and pollutants through source reduction

(ii) diverting at least 50 percent of non-hazardous solid waste, excluding construction and demolition debris, by the end of fiscal year 2015

(iii) diverting at least 50 percent of construction and demolition materials and debris by the end of fiscal year 2015

(iv) reducing printing paper use and acquiring uncoated printing and writing paper containing at least 30 percent postconsumer fiber; chemicals and materials acquired, used, or disposed of

(v) increasing diversion of compostable and organic material from the waste stream"

4.1.2 DoD Goals

The DoD SSPP has parallel goals for waste diversion(DoD, FY2012). This is consistent with past waste reporting, and management practices.

“Goal 5 Solid Waste Minimized and Optimally Managed

- Sub-Goal 5.1 All DoD Components implementing policies by FY 2014 to reduce the use of printing paper
- Sub-Goal 5.2 50% of Non-Hazardous solid waste diverted from the waste stream by FY2015, and Thereafter Through FY 2020
- Sub-Goal 5.3 60% of Construction and Demolition Debris Diverted from the Waste Stream by FY 2015, and Thereafter Through FY 2020
- Sub-Goal 5.4 Ten landfills or wastewater treatment facilities recovering biogas for use by DoD by FY 2020.”

4.1.3 Army goals

The ASA-IEE Net Zero program (http://www.asaie.army.mil/Public/ES/netzero/) challenges installations to achieve zero landfill disposal (Figure 42). The concept of Net Zero Waste simply states that, during the course of any given year, no waste should go to the landfill. A combination of different waste management practices should be applied to accomplish this goal. These practices are divided in two main components: waste minimization and waste diversion. The waste minimization component of the Net Zero Strategy encourages installations to reduce the waste at the source by engaging in sustainable purchasing of materials that generate less waste, have less packaging, are reusable or recyclable, i.e., "green procurement." The second component, waste diversion, refers to the processes and technologies the installation can use to avoid waste going to the landfill. Examples of alternatives to landfill disposal, among many others, are reusing materials, recycling and composting, and waste-to-energy technologies. Per discussions among this community, guidance is to strive for a minimum of 50% diversion through recycling/composting, with source reduction and waste to energy comprising the balance. Waste to energy seems attractive in some situations, but it shouldn't be regarded as a blanket solution. While Fort LW is not part of the initial Net Zero pilot group of installations, it is anticipated that this program will expand, with lessons learned compiled from the first group.

Figure 42. Net Zero waste strategy.

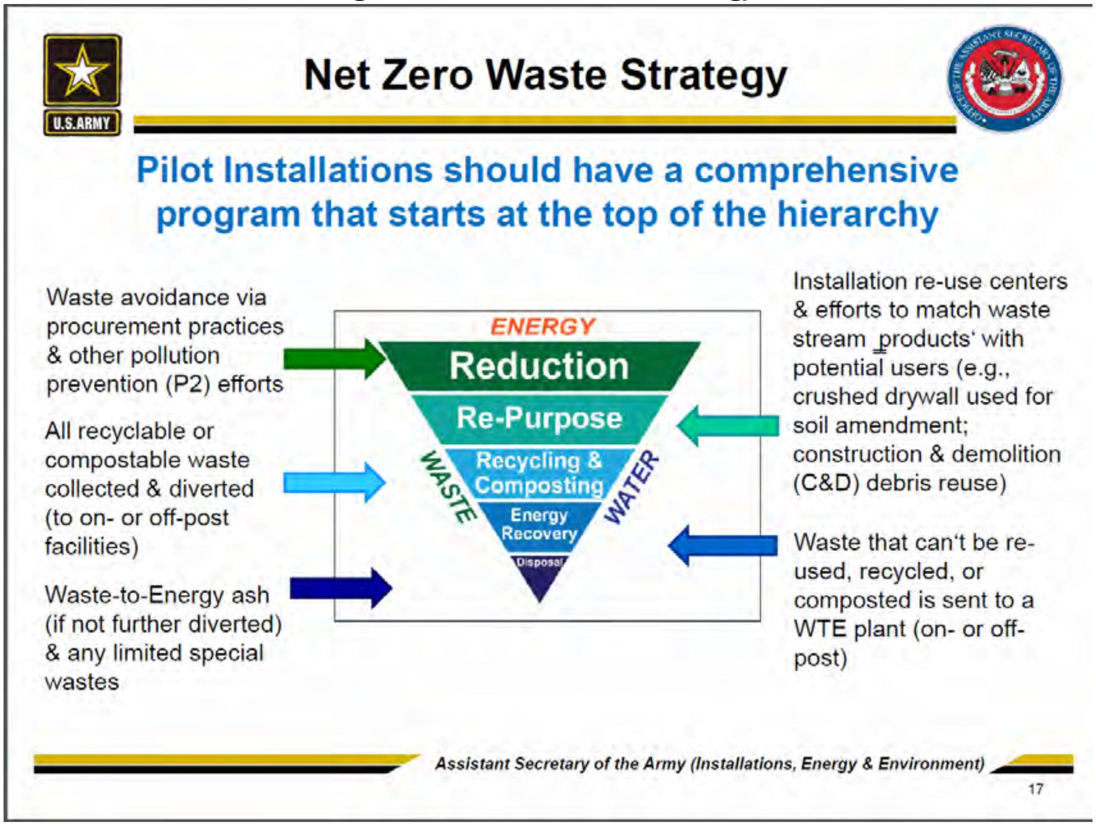


Table 62 presents some of the main policies applicable to C&D waste and their respective diversion goals.

Table 62. Policies and their applicability to C&D waste.

Source	C&D Waste Reduction Criterion
Executive Order 13514 Federal Leadership in Environmental Leadership in Environmental, Energy, and Economic Performance	" … diverting at least 50 percent of construction and demolition materials and debris by the end of fiscal year 2015."
Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding	"Program the design to recycle or salvage at least 50 percent construction, demolition and land clearing waste … "
Office of the Secretary of Defense, Integrated (Non-Hazardous) Solid Waste Management Policy, 01 February, 2008	"The goal for C&D waste is 50% diversion by 2010."
OSD Integrated (Non-Hazardous) Solid Waste Management Policy, 01 February, 2008	"Waste-to-energy recovery is not considered diversion for the solid waste diversion goal, although it is applicable to the energy reduction goals of EO 13423."
Department of Defense Strategic Sustainability Performance Plan FY2012	"60% of Construction and Demolition Debris Diverted from the Waste Stream by FY 2015,

Source	C&D Waste Reduction Criterion
	and thereafter through FY 2020”
Office of the Assistant Chief of Staff for Installation Management Memorandum of 6 February, 2006, Revised 5 July 2006	“The 50 percent minimum diversion of C&D wastes from landfills is a requirement for each project undertaken or contract awarded at an installation or activity.”
DoD Strategic Sustainability Performance Plan (SSPP), annual.	“Reduce C&D waste incrementally from 50%, by 2%/year to 60% by FY2015.”
Office of the Assistant Secretary of the Army, Installations, Energy, and Environment (AOSA-IE&E) Sustainable Design and Development Policy Update, 17 December 2013.	“Requires 60% C&D debris reduction consistent with the DoD ISSP; also requires, when buildings are being removed, deconstruction be evaluated and implemented where markets exist or are anticipated.”

4.1.4 Fort Leonard Wood goals

Fort Leonard Wood has developed the Integrated Strategic Sustainability Plan with different goals towards sustainability. Their strategic goal 1 relates to Sustainable Development and Redevelopment at Fort Leonard Wood.

> “Objective 1.3: By 2035, develop new and modernize existing facilities to perform at net-zero with respect to energy, water, and waste while providing a high quality of life and adaptable work environment.”

Fort Leonard Wood has the goal to become a Net Zero Waste installation by 2035. Some measures that had been taken into consideration as part of this objective are the reduction in waste disposal from source reduction, reuse, use of natural/degradable products, and increased recycling.

4.2 Baseline

4.2.1 Annual full time waste generator equivalent

The ERDC-CERL team evaluated Fort Leonard Wood’s population data obtained from the Army Stationing and Installation Plan (ASIP 2013). The team determined that not all the population on post generates waste at the same rate. Thus, their contribution to the waste stream had to be evaluated. The military population that works in a full time basis on post is divided between the ones who actually reside on post and the ons who are non-residents. It was estimated that the non-residents generate a third of the waste that a full time resident would generate as well as the civilians that work on post. Also the annual average of the transient military, which is temporary on post, was taken into account as a full time generator. The same assumption was made for the weekly average of transient civilians. The total generated by adding these population groups defines the Annual Full Time Waste Generator Population Equivalent. Table 63 presents these values based on the ASIP data obtained.

Table 63. Annual full time waste generator population equivalents for Fort Leonard Wood from FY2006 to FY2013.

Population Category	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013
Full Time Military - Residents	2954	2966	3377	3751	3883	3960	3868	3886
Full Time Military - Non Residents	2954	2966	3377	3751	3883	3960	3868	3886
Full Time Civilian - Non Residents	6,023	5,866	6,324	6,289	6,455	6,549	6,627	7,021
Transient Military (Monthly Average)	1486	1662	1635	1728	1556	1552	1466	1522
Transient Civilian (Weekly Average)	2	2	1	1	1	2	2	2
Annual Full Time Waste Generator Population Equivalent	7434	7575	8246	8827	8886	9018	8835	9046

4.2.2 Annual solid waste reporting

The Solid Waste Annual Reporting (SWAR) system is a data management system designed to facilitate tracking and reporting of solid waste and recycling data at Department of Defense facilities (DENIX 2013). All Army installations report their solid waste data for each FY in this system. Using this system, the Army has estimated that installations generate an average o 3 lbs per person per day of solid waste (ACSIM 2012). The ERDC-CERL team obtained Fort Leonard Wood's data for FY2005 to FY2012. Data for FY2005 included waste generated by the population from the family housing. This data was not found from FY2006 and later, therefore it was removed from our analysis. Table 64 presents a summary of the reported data for MSW from FY2005 to FY2012. FY2005 is presented for information purposes but removed from our analysis.

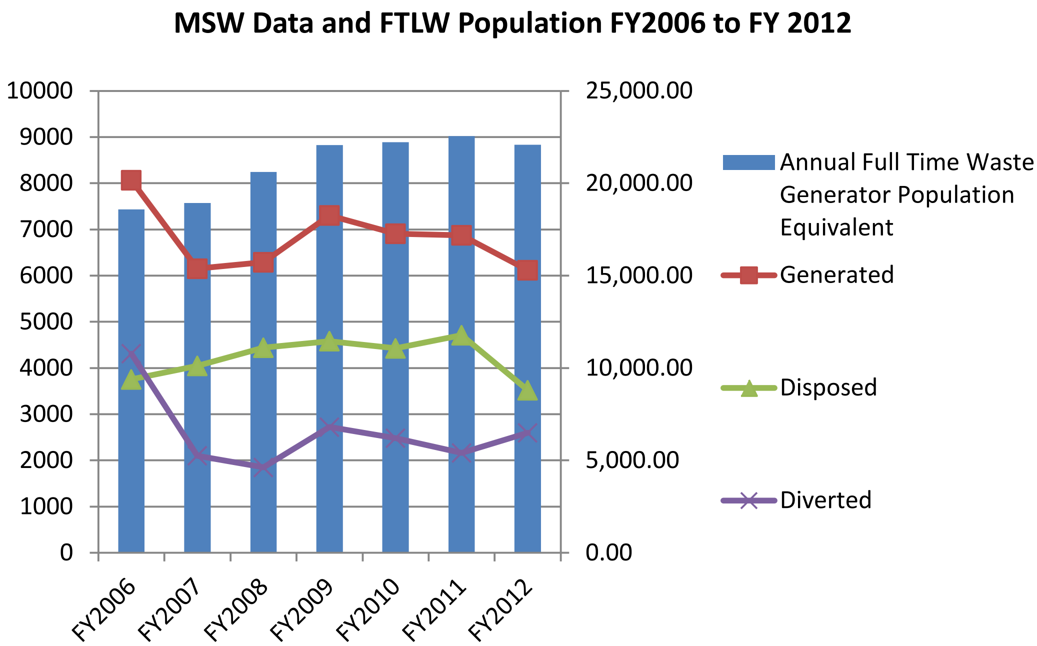
Table 64. Municipal solid waste generated, disposed and diverted in tons from FY2005 to FY2012.

Waste Category for MSW	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012
Generated	20,166.86	15,376.86	15,725.75	18,261.39	17,272.29	17,187.03	15,295.39
Disposed	9,385.27	10,120.79	11,104.31	11,458.67	11,066.34	11,778.83	8,801.15

Diverted	10,781.59	5,256.07	4,621.44	6,802.72	6,205.95	5,408.20	6,494.24
Percent Diverted	53%	34%	29%	37%	36%	31%	42%

Figure 43 presents the relationship between the annual full time waste generator population equivalents and waste generated, disposed, and diverted. While it seems obvious, it is important to point out that waste generation increased if the population in a given year increased. An exception to that happens in FY 2006. That was the year (in our study scope) when the most waste was generated.

Figure 43. MSW and population comparison.



The data presented in the following two figures (Figure 44 and Figure 45) shows that waste diversion increased significantly in FY2012 compared to FY2011, even though the population and the waste generation were reduced. Fort Leonard Wood is approaching the waste diversion goal but still is not there yet. Diversion will have to increase by an approximate 8% in order to reach the 50% diversion goal.

Figure 44. Graphical description of how close is Fort Leonard Wood to the 50% diversion goal.

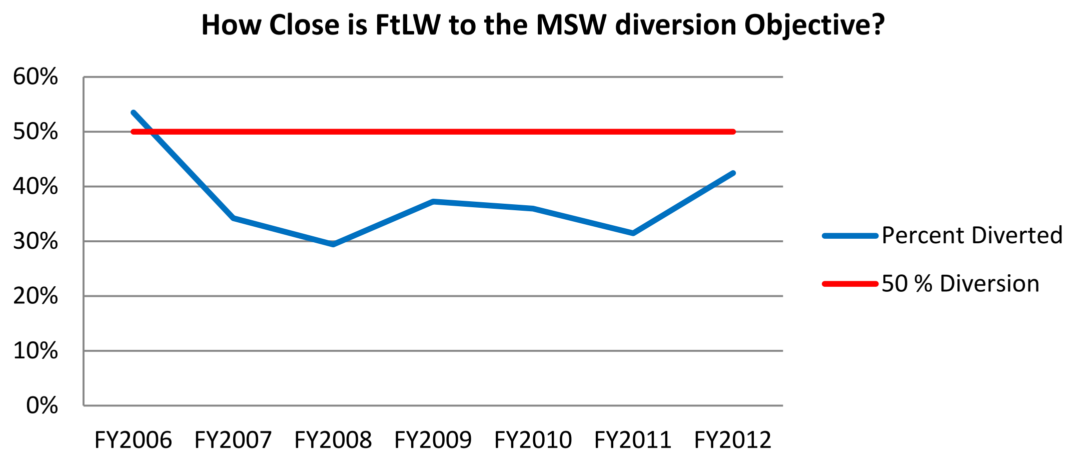
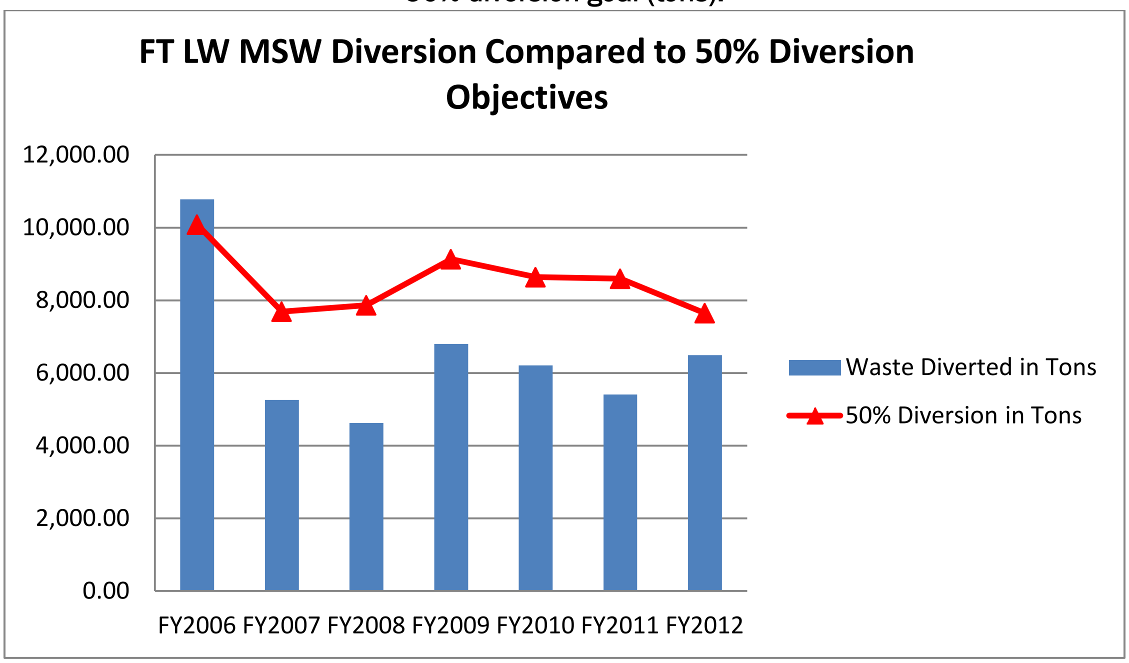


Figure 45. Graphical description of how Fort Leonard Wood diversion compares to the 50% diversion goal (tons).



Fort Leonard Wood's C&D recycling rates are presented in Table 65. Even though the C&D recycling rates are relatively high, the SWAR indicates that throughout the period of 2010 through 2012 4,196 tons (62%) of asphalt/brick/concrete (ABC) was recycled, 150 tons (less than 1%) of metals was recycled, and 12,100 tons (37%) of "Other" C&D materials were recycled. No wood from C&D activities was recycled from FY 2010 – 2012. A potential exists to significantly reduce Fort Leonard Wood's solid waste stream by reusing as well as recycling materials generated while removing wood buildings, especially WWII-era wood buildings.

Table 65. Construction and demolition waste generated, disposed and diverted in tons from FY2005 to FY2012.

Waste Category for C&D	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012
Generated	41,080.00	16,310.00	3,470.00	14,768.00	12,197.95	12,419.42	21,335.53
Disposed	18,855.00	6,050.00	0	7,250.00	5,010.00	4,436.88	7,561.97
Diverted	22,225.00	10,260.00	3,470.00	7,518.00	7,187.95	7,982.54	13,773.56
Percent Diverted	54%	63%	100%	51%	59%	64%	65%

Table 65 illustrates how reported C&D diversion rates compare to the 60% diversion objective. Even though at first glance it seems that Fort Leonard Wood is on track by meeting the diversion objective, there is opportunity for diversion for many other C&D materials that are currently being disposed. The Cost Avoidance data in the SWAR indicates a C&D disposal cost of $48/ton. The USACE project office indicates tipping fee is $50/ton at the local transfer station, plus hauling.

The recent SWAR diversion data presents three areas in which a great improvement in reducing C&D waste can be achieved.

- The reuse value of wood materials has been ignored. The typical disposition of C&D wood in the commercial market is to either landfill it or recycle it as boiler fuel. If current Army practice is to recycle wood debris at commercial C&D recycling facilities, the Army is gaining no value from it, as incineration does not count toward diversion. If current Army practice is to landfill wood debris, even a modest cost reduction in disposing debris at a C&D recycling facility is lost. The potential exists to capitalize on an emerging market in the reuse of salvaged timber and lumber products.
- Almost no C&D metals were recycled. If 150 tons diverted represents less than 1% (0.21% reported), then over 70,000 tons was not diverted in those three years. Given the almost standard practice in the demolition industry of recycling scrap metals, it is unusual that this income potential is not being tapped.
- Almost two-thirds of “other” C&D materials were not recycled. If 12,100 tons represents roughly one-third of the “other” C&D waste stream, then over 20,000 tons was not diverted. The “other” category

typically includes miscellaneous materials that are often described as difficult to recycle. However, much can be recycled or salvaged for reuse. Examples include glass, asphalt shingle roofing, plastics, carpet, doors and windows, ceilings, insulation, and some plumbing, mechanical, and electrical equipment. Packaging and packing also contributes a significant amount to the C&D waste stream. Reducing the "other" C&D waste stream by a significant amount should be realistic.

Figure 46. C&D diversion compared to objectives.

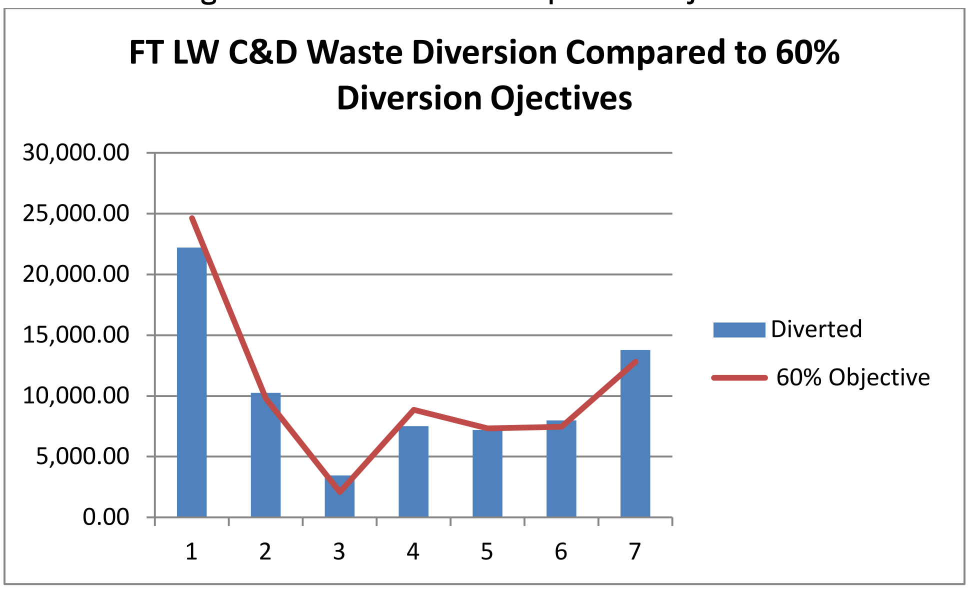


Table 66 presents the reported waste diverted via composting at Fort Leonard Wood. Composting during the studied period has been low. Fort Leonard Wood should expand their composting operation since the installation generates enough organic materials to sustain a full scale composting facility. Some alternatives that will help to increase these numbers are discussed further in the chapter.

Table 66. Waste diverted via composting in tons from FY2005 to FY2012.

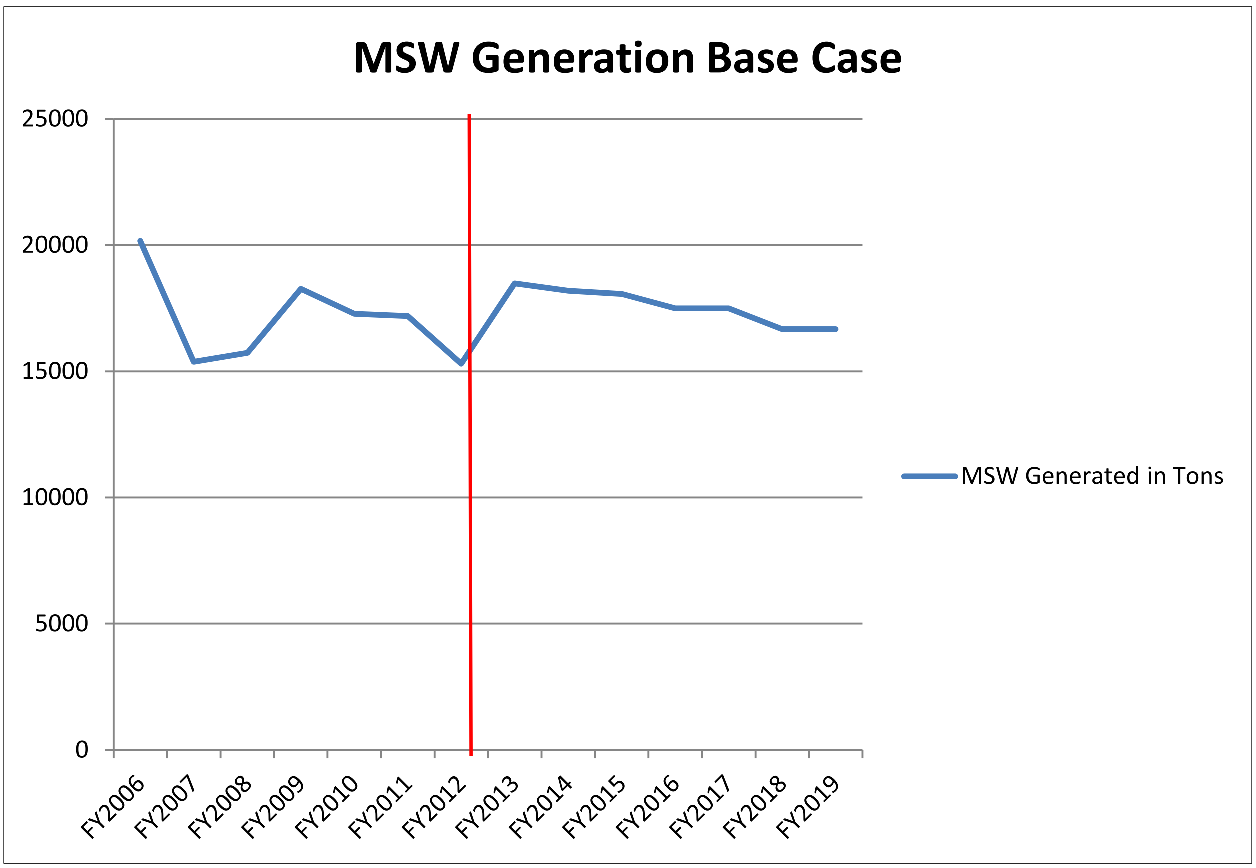
FY2005	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012
0	3,880.00	1,846.90	646	1,465.50	294.40	401.50	0.00

4.3 Base case

4.3.1 MSW projection

The MSW and population data described in the previous section was the basis for all of the projections presented in this section as a Base Case. The ERDC-CERL team calculated an annual per capita waste generation rate in tons based on the population and generation data obtained from ASIP and SWAR respectively. Our calculations provided an average of 2.04 tons per person per year from FY2006 to FY2012. After obtaining the average generation rate value and knowing projected population data up to FY2019, it was possible to calculate a waste generation projection (Figure 47).

Figure 47. MSW generation projections.



4.3.2 Demolition waste projection

Demolition projects contribute greatly to the overall solid waste burden. Because demolition projects are managed by separate offices, under different programs, one doesn't often look at the overall impact, or try to develop waste recycling strategies. Table 67 gives a snapshot of the demolition waste expected in FY2014, broken down by building type and material type. Summing the projected material generation from all demolition projects scheduled via the Facility Reduction Program yields the waste projections in Table 68.

Table 67. Projected of demolition waste to be generated FY2014 (tons).

Bldg Type	MSW	Paper	Organics	Wood	Metals	Concrete	Plastics	Mixed Recyclables
Admin, one-story 1960	836	47	-	373	66	735	6	6
Admin, one-story, 1970	1,004	56	-	448	79	883	8	8
Training, one-story	517	29	-	231	41	455	4	4
DFAC, 1960	393	22	-	176	31	346	3	3
Barracks, Enlisted, 1960	233	13	-	104	18	205	2	2
Industrial, TEMF	2,894	162	-	1,292	229	2,547	22	22
Industrial, Light, Generic	52	3	-	23	4	45	0	0
Warehouse, WWII wood	117	0	1	131	7	281	1	-
Totals	6,044	333	1	2,777	476	5,498	46	45

Table 68. Total projected demolition waste to be generated (tons).

Year	MSW	Paper	Wood	Metals	Concrete	Plastics	Mixed Recyclables	Annual Total
2014	6,044	333	2,777	476	5,498	46	45	15,219
2015	1,926	102	939	150	1,874	14	14	5,020
2016	8,667	480	3,948	683	7,807	66	65	21,717
2017	996	50	524	76	1,055	7	7	2,715
Mat'l total	17,634	965	8,188	1,385	16,234	133	131	

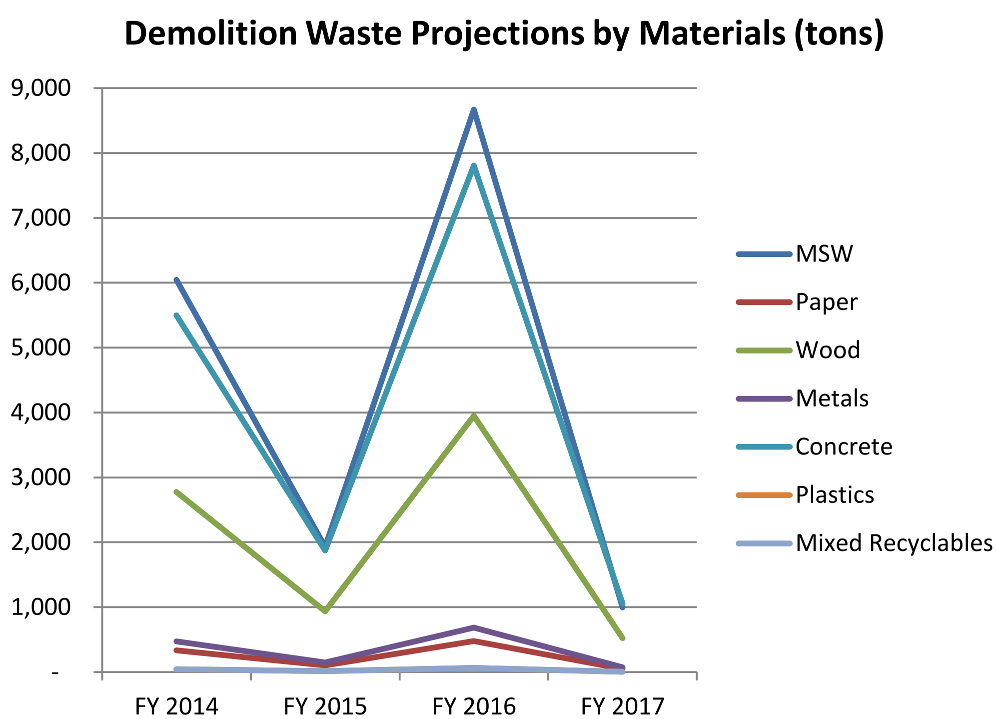
Fort Leonard Wood requires a mechanism by which they can quickly determine the types and quantities of reusable, recyclable, and debris materials generated by construction and demolition projects. C&D waste and reuse and recycling opportunities can then be incorporated into Fort Leonard Wood's overall solid waste reduction strategies. ERDC-CERL has created waste generation models for both new construction waste, and demolition waste from common Army building types (see section 5.3.2.1).

Waste from new construction projects waste computed in the same fashion as demolition materials, above. We are tracking the same materials in each case, but the amount generated per square foot of building is much less. The figures in Table 69 and Figure 48 below are based on MILCON project plans for FY2014, 2015, 2016 and 2017.

Table 69. Total projected new construction waste to be generated (tons).

Year	MSW	Paper	Wood	Metals	Concrete	Plastics	Mixed Recyclables
2014	989	241	1140	131	1991	38	293
2017	223	54	257	31	450	9	66
Total	1212	296	1397	163	2441	46	359

Figure 48. Graphic representation of demolition waste projections.



4.3.2.1 Creating models

Performing a quantity take-off for a building is a routine but time consuming exercise. Recreating take-offs for each obsolete building to be demolished would not be feasible. Instead, a parametric estimating method is preferred.

The Corps of Engineers and Army have developed families of standard designs for facilities. One standard design represents multiple buildings, perhaps several hundred for a common facility type at one installation. Similar facility types (such as administrative facilities and training facilities) were often designed within the same family of standard designs, applying the same construction type and materials. On a per-square-foot basis, their designs are similar enough that they can be described as essentially the same building type. The uniformity of buildings' design and construction within families of standard designs suggests modeling construction waste and debris streams, as opposed to performing individual quantity take-offs, would be a feasible approach to projecting future waste quantities. Facility type, scope (in square feet), and date of construction are three parameters by which most buildings on Fort Leonard Wood can be described. Knowing the specific facilities to be demolished, one can then approximate future demolition debris and construction waste streams without taking-off quantities of each building.

Altogether, 20 building models were created to represent the majority of Fort Leonard Wood buildings that would be demolished within the foreseeable future. They are:

- Residential (representing Family Housing)
- Administrative Buildings (1960s era, each 1, 2, and 3 story)
- Administrative Buildings (1970s era, each 1, 2, and 3 story)
- Administrative & Supply Buildings (1960s era)
- Administrative & Supply Buildings (1970s era)
- Training Buildings (each 1 and 2 story)
- Consolidated Mess
- Commissary
- Barracks / Quarters (1960s era)
- Barracks / Quarters (1970s era)
- Light Industrial (motor repair)
- Light Industrial (other)
- Warehouse (WWII-era wood)
- Warehouse (masonry construction)
- Warehouse (pre-engineered metal building construction)

4.3.2.2 Data sources

The USEPA published a report authored by the Franklin Institute in 1998 entitled *Characterization of Building Related Construction and Demoli-*

tion Debris in the United States. This report estimates the total amount debris generated by demolition, renovation, and new construction activities annually nationwide in residential and non-residential markets. These estimates also included relative quantities of wood, metal, concrete, roofing, gypsum wall board, plastics, and miscellaneous materials, as percentages of the total debris for each category. On the surface, this data could be useful in creating models for Army installations. Unfortunately, the sample size on which this data was generated was very small, and would not adequately represent Army buildings. Furthermore, data was inconsistent among the building categories. Finally, this report referred to all building material as debris. It did not distinguish among materials that could be recovered for reuse, recycled for a secondary process, or disposed of in a landfill.

A more robust characterization of C&D materials was found in a 2006 report authored by the Cascadia Consulting Group for the California Integrated Waste Management Board entitled *Detailed Characterization of Construction and Demolition Waste.* Similar to the USEPA report, the CIWMB report provides C&D materials data for residential and non-residential buildings, and new construction, renovation, and demolition activities. It used a much larger building sample and provided uniform data among all categories. C&D materials were subdivided into the paper, glass, metals, electronics, plastics, organic materials, construction and demolition materials, household hazardous waste, and special waste. Each of these categories was further subdivided into 85 line items. Each line item represents a percentage of the total C&D waste stream for each category, by weight. Using this data, and knowing a building's weight, one can apply the materials percentages to determine the quantity of each material. The CIWMB report also described recyclable materials within the debris stream.

While it represents California buildings, it was felt the CIWMB data was representative of building design and construction throughout the U.S. ERDC-CERL used this source to determine the relative quantities of each constituent building material for each building category.

The Whitestone Building Maintenance and Repair Cost Reference, published by Whitestone Research, provides quantity take-offs for 24 common commercial building types. For each building type, the quantities of materials and components for exterior closure, roofing, interior construction, plumbing, HVAC, fire protection, and electrical systems are provided. These quantities were normalized to a per-square-foot quantity for each model building, which then could be applied to Army buildings.

The Whitestone data does not include foundation or structural systems, as they are not generally included with routine maintenance and repair requirements. Quantity take-offs were performed on construction documents for Army buildings. These quantities were also normalized to a per-square-foot quantity for each Army model and added to the Whitestone quantity data. Take-offs from interior construction and exterior envelope components were also performed on the Army model buildings. Where the actual take-offs varied significantly (about 10%) from the Whitestone Models, the actual take-off quantities were used. Where construction materials differed from the Army models, actual Army model construction materials were used. Using the combination of Whitestone and actual Army building take-offs, per-square-foot quantities of all building materials were developed for each Army model building type.

Weights of building materials were identified using a variety of sources that included standard building material weight tables, vendor shipping weight data, and manufacturer data. Weights were then applied to the quantity per-square-foot data to provide a weight-per-square foot value for each Army model building type. This data can then be applied to any size of Army building of a similar type.

Figure 49 provides an estimate of new construction waste and demolition debris streams for a 16,784 square foot 2-story administrative-type building, similar to buildings within category code 610.

One spreadsheet was developed for each model building type. Given a square foot scope for a specific building, per-square-foot of new construction debris, per per-square-foot of demolition debris, total new construction debris, and total demolition debris estimates are estimated. Estimates of recyclable material quantities are also given, as are packing/packaging materials for new construction projects. Given a building removal requirement at an installation, a total estimated debris stream for multiple buildings can then be calculated.

Fort Leonard Wood has programmed 33 building to be removed in FY2014. Table 70 shows the buildings on the FY14 demolition list, along with the building models associated with each Fort Leonard Wood building.

Figure 49. Construction and demolition waste model, two-story administrative-type building.

NET ZERO WASTE
FACILITY TYPE:

CONSTRUCTION & DEMOLITION WASTE QUANTITY MODEL
ADMINISTRATIVE BUILDINGS 1960's -era
CAT CODE: 610 AND SIMILAR

Office, 2 story	(ENTER BUILDING SQUARE FOOT AREA HERE)		16,784	SF				
New construction waste (APPROX, INCL CONCRETI		12 Lbs/SF,	201,408	lbs total				
Demolition debris (APPROX)		137 Lbs/SF,	2,299,408	lbs total				
	NEW CONSTRUCTION WASTE				DEMOLITION DEBRIS			
	Percent	Lbs/SF	Sample building, Lbs 16,784	SF	Percent	Lbs/SF	Sample building, Lbs 16,784	SF
Mixed MSW - unsorted mixed waste, default to landfill	20.9%	2.51	42,094	LBS	39.2%	53.704	901,368	LBS
Paper - including source separated office paper and OCC	5.1%	0.61	10,272	LBS	2.2%	3.014	50,587	LBS
Organics - food, yard waste	0.1%	0.01	201	LBS	1.3%	0	-	LBS
Wood - both natural and from construction and packaging	24.1%	2.89	48,539	LBS	17.5%	23.975	402,396	LBS
Metals - ferrous and non-ferrous together because the management will be similar	3.6%	0.02	254	LBS	3.1%	4.247	71,282	LBS
Concrete and asphalt concrete - counted together due to similar "measures"	42.1%	5.05	84,793	LBS	34.5%	47.265	793,296	LBS
Plastics - all types, source segregated	0.8%	0.10	1,611	LBS	0.3%	0.411	6,898	LBS
Mixed consumer recyclables - bottles, cans, papers, collected together, to be sorted at a centralized facility	6.2%	0.74	12,487	LBS	0.3%	0.411	6,898	LBS
Biosolids - from WWTP; plus similar wet sludges	0.0%	0.00	-	LBS	0.0%	0	-	LBS
Medical - "red bag" materials; NA		0.00	-	LBS		0	-	LBS
Ash - inert, inorganic, probably landfilled	0.0%	0.00	-	LBS	0.0%	0	-	LBS

Recyclable materials			16,784	SF			16,784	SF
Recyclable aggregates	12.0%	1.44	24,169	LBS	12.0%	16.44	275,929	LBS
Recyclable wood	27.9%	3.35	56,193	LBS	27.9%	38.223	641,535	LBS
Recyclable rock, dirt, & sand	6.7%	0.80	13,494	LBS	6.7%	9.179	154,060	LBS
Recyclable metal	3.1%	0.37	6,244	LBS	3.1%	4.247	71,282	LBS
Other recoverable material		0.00	-	LBS		0	-	LBS
Paper	3.7%	0.44	7,452	LBS	3.7%	5.069	85,078	LBS
Glass	0.2%	0.02	403	LBS	0.2%	0.274	4,599	LBS
Plastic	0.5%	0.06	1,007	LBS	0.5%	0.685	11,497	LBS
Organics	5.0%	0.60	10,070	LBS	5.0%	6.85	114,970	LBS
Construction / Demolition	16.7%	2.00	33,635	LBS	16.7%	22.879	384,001	LBS
Materials packing / packaging materials			16,784	SF			16,784	SF
Uncoated corrugated cardboard	2%	0.20	3,424	LBS				
Pallets & crates	5.4%	0.65	10,876	LBS				
Film	0.3%	0.04	604	LBS				
EPS packaging/insulation	0.0%	0.00	-	LBS				

Table 70. FY14 Fort Leonard Wood demolition program and model building types.

Fort Leonard Wood FY 14 Demolition			
Number	Building Type	SQFT	C&D Debris Estimating Model
711	Company HQ Builidng	2,400	admin buildings 1 story 1960s
712	Company HQ Builidng	2,400	admin buildings 1 story 1960s
713	Separate Toilets/Showers	2,400	admin buildings 1 story 1960s
714	Company HQ Builidng	2,400	admin buildings 1 story 1960s
715	Company HQ Builidng	2,400	admin buildings 1 story 1960s
716	Gen. Instruction Bldg.	2,400	training buildings 1 story
717	Gen. Instruction Bldg.	2,400	training buildings 1 story
718	Gen. Instruction Bldg.	2,400	training buildings 1 story
719	Gen. Instruction Bldg.	2,400	training buildings 1 story
758	Barracks	2,400	barracks 1960s
759	Barracks	2,400	barracks 1960s
760	Separate Toilets/Showers	2,400	training buildings 1 story
763	Gen. Instruction Bldg.	2,400	training buildings 1 story
764	Gen. Instruction Bldg.	2,400	training buildings 1 story
2349	Heating Plant	900	light industrial, other
2351	Heating Plant	4,113	light industrial, other
2352	Laundry	49,379	warehouse ww2 wood
2385	Organizational Struct Bldg	3,203	admin buildings 1 story 1960s
2565	Warehouse	18,280	warehouse ww2 wood
5073	Conosolidated Mess	9,600	consolidated mess 1960s
5076	Gen. Instruction Bldg.	1,000	admin buildings 1 story 1970s
6120	Covered Training Area	1,589	warehouse pre-eng metal
6121	Separate Toilets/Showers	300	admin buildings 1 story 1970s
6124	Support Facility	512	warehouse masonry
6125	Support Facility	800	warehouse masonry
6127	Separate Toilets/Showers	300	admin buildings 1 story 1970s
8370	Chapel	6,182	warehouse ww2 wood
9611	PVT Organizational Club	2,908	consolidated mess 1960s
9613	PVT Organizational Club	5,816	consolidated mess 1960s
9615	PVT Organizational Club	4,332	consolidated mess 1960s
9617	PVT Organizational Club	4,944	consolidated mess 1960s
9619	PVT Organizational Club	5,816	consolidated mess 1960s
12404	Covered Training Area	16,000	warehouse pre-eng metal

The 33 individual buildings on the FY14 Fort Leonard Wood are represented by eight building models. Note that every Fort Leonard Wood building is not a perfect fit for some model building types. Without knowing each building on the demolition list individually, some assumptions had to be made when associating them with the model building types. For example, the Separate Toilet/Shower facilities were most likely parts of a barracks complex consisting of multiple 2,400 SF buildings, which have since been converted to various training and administrative occupancies. Thus, the Separate Toilet/Shower buildings are grouped into the training or administrative facilities in which they are located. Also, Covered Training Areas are essentially pre-engineered metal buildings without walls. Applying the pre-engineered metal building warehouse model to them will result in a slight over-estimate (roughly 6%) of the buildings' total weight. However, these models are intended to provide an approximation of potential debris streams, not precise estimates. Aggregating the square foot area of similar building models should result in a debris estimate suitable for the purposes.

The square foot totals for each model building type are as follows:

Admin Buildings 1-Story 1960s	16,803
Training Buildings 1-Story	16,800
Light Industrial, Other	5,013
Warehouse WWII-era wood	73,841
Consolidated Mess 1960s	33,416
Warehouse Masonry	1,312
Warehouse Pre-Eng Metal	17,589

4.4 Alternatives

Tables detailing the alternatives are on the following pages.

4.4.1 Alternative 1: Comingled recycling, open windrow composting and wood recovery of WWII-Era Buildings

	Measures		
	Implementation of a Comingled Recycling Program	Organic Waste Diversion: Open Windrow Composting	Expansion of C&D recycling program to add recovery of wood from WWII-Era Buildings
Resources Needed	Baling Equipment Mixed Recyclables Containers Contract with a Material Recovery Facility (e.g. Resource Management, located outside of St. Louis, MO) Collection Vehicles and Personnel Need to decide which materials to include. For example, it might be beneficial to continue separate collection of white paper, and cardboard because those items are relatively easy to keep separate, and command a higher price.	Fenced Composting Site Composting Pad Compost Material Containers Compost Material Collection Vehicles and Personnel Compost Material Grinding/Chipping Equipment Windrow Processing Equipment Permits	Introduction of demolition contractors, as the potential prime contractors, to other specialty contractors and lumber salvagers who do possess the specialty skills and experience to recover lumber for reuse. A survey of other FLW offices and agencies is suggested as identifying on-post reuse opportunities. Change of contract requirements to include a C&D waste management and reduction Plan.
Initial Investment Cost		Construction of Composting Site* Equipment	Typically cost neutral, possibly slight increase. For FY14 WWII-era building removal: Estimated demolition cost: $900,000 Possible cost increase of 5% (if any): $45,000 Cost avoidance; 570 tons @ $48/ton: $27,360 Net cost increase (if any) $17,640 (i.e.<2%) Value of recovered material is NOT included
Estimated Diversion Rate Increase		With a good organic waste management plan in place all food (realistically pre-consumer food waste), yard, manure and pulverized paper waste generated could be diverted by using this measure.	75% of wood for reuse is realistic; 90% total diversion (reuse and recycling) is realistic

* Based on a previous feasibility study made for Fort Polk, LA (ERDC 2013). Cost will vary for FtLW.

4.4.2 Alternative 2: Comingled recycling, static pile composting, and concrete recycling site

	Measures		
	Implementation of a Comingled Recycling Program	Organic Waste Diversion: Static Pile Composting	Concrete Recycling Site
Resources Needed	Baling Equipment Mixed Recyclables Containers Contract with a Material Recovery Facility (e.g. Resource Management, located outside of St. Louis, MO) Collection Vehicles and Personnel Need to decide which materials to include. For example, it might be beneficial to continue separate collection of white paper, and cardboard because those items are relatively easy to keep separate, and command a higher price.	Fenced Composting Site Composting Pad Compost Material Containers Compost Material Collection Vehicles and Personnel Compost Material Grinding/Chipping Equipment Static Pile Equipment: Blowers and piping Permits	Consider establishing a concrete recycling site, using the concrete generation projections herein to scope it. It might be possible to coordinate Engineer School training activities at the quarry site to help process waste concrete for beneficial, on-post use. ERDC-CERL is pursuing funding options for a small scale demonstration of this idea, whereby scrap concrete of specific dimensions might be used to augment natural habitat for the Hellbender salamander.
Initial Investment Cost		Construction of Composting Site* Equipment	
Estimated Diversion Rate Increase		With a good organic waste management plan in place all food (realistically pre-consumer food waste), yard, manure and pulverized paper waste generated could be diverted by using this measure.	

* Based on a previous feasibility study made for Fort Polk, LA (ERDC 2013). Cost will vary for FtLW.

4.4.3 Alternative 3: Comingled recycling, in vessel composting, and concrete recycling site

	Measures		
	Implementation of a Comingled Recycling Program	Organic Waste Diversion: In Vessel Composting	Concrete Recycling Site
Resources Needed	Baling Equipment Mixed Recyclables Containers Contract with a Material Recovery Facility (e.g. Resource Management, located outside of St. Louis, MO) Collection Vehicles and Personnel Need to decide which materials to include. For example, it might be beneficial to continue separate collection of white paper, and cardboard because those items are relatively easy to keep separate, and command a higher price.	An average In-Vessel system may occupy a footprint of approx 500SF plus additional area to cure the compost (if used for landscaping). Composting Hardware Compost Material Grinding/Chipping Equipment As this is a small system it could be located close to a food waste generator (e.g. DFAC) and food waste transportation logistical issues might be avoided Electrical Utilities Personnel to load materials into equipment Personnel to maintain the equipment	Consider establishing a concrete recycling site, using the concrete generation projections herein to scope it. It might be possible to coordinate Engineer School training activities at the quarry site to help process waste concrete for beneficial, on-post use. ERDC-CERL is pursuing funding options for a small scale demonstration of this idea, whereby scrap concrete of specific dimensions might be used to augment natural habitat for the Hellbender salamander.
Initial Investment Cost		100k-300k for composting equipment depending on processing capacity* 20k for shredding equipment	
Estimated Diversion Rate Increase		For equipment capable of processing 1,500 lbs a day it is recommended to distribute between food waste and yard/manure waste.	

* Based on Cost Benefits Analysis performed for an In-Vessel System at Joint Base Meyer-Henderson Hall (NDCEE 2013)

4.4.4 Guidance and definitions for alternatives

4.4.4.1 Commingled recycling option

Currently, Fort Leonard Wood's the DPW (via contract) collects, bales, and markets a variety of recyclable materials including consumer plastic and metal containers, white paper, and cardboard. The bales are placed on a trailer belonging to a material broker company. Different materials are kept separate throughout the collection processes, from the collection point, through on-post processing, to the end market.

Figure 50. Baler at Fort Leonard Wood's recycling center.

Figure 51. Recycling drop off trailer and sorted recyclable materials at recycling center at Fort Leonard Wood.

The annual reported recycling processing cost is about $170k, An alternative to the process described above, is to collect all (or selected) recyclables in a commingled fashion, i.e., all the recyclables to into one container in a common area, or office building. This process has become more popular since the 1990s across the US, including in Missouri. This is sometimes known as single stream recycling. These materials could then be brought to a recycling center, and baled together. These commingled bales could be sent to a Material Recovery Facility (MRF) that has sophisticated, automated sorting systems that would break apart these bales into sorted streams of desirable commodities (e.g., cans, plastics, paper). As part of this study, the ERDC-CERL team visited one such MRF, Resource Management (RM) that is located outside of St. Louis, MO (Figure 53). The team determined that Fort Leonard Wood's commingled recyclable materials could be baled on-post and sent to RM's facility. RM has the capability of picking up the materials for a fee. By doing so the installation could eliminate the cost of collecting recyclables separately.

Figure 52. Example of baled materials.

Below we present a list of trade-offs (pros and cons) that must be evaluated to figure out the net benefit of this approach:

- Collection and processing costs would decrease
- Possible to ship unbaled material, albeit at a higher unit shipping cost. It might be possible to haul loose materials directly to a transfer station for shipment to the MRF.
- Direct shipping cost increase

- The price received for the materials would vary, but likely the net price would be lower than trying to get the best price for individual commodities
- Need to decide which materials to include. For example, it might be beneficial to continue separate collection of white paper, and cardboard because those items are relatively easy to keep separate, and command a higher price.
- There is currently very little market for glass and polystyrene. When doing commingled recycling, the price received would be higher if these materials were kept out, however this might confuse users and reduce overall participation.

Figure 53. Recyclable processing equipment at Resource Management.

4.4.4.2 Organic waste diversion options

Fort Leonard Wood generates a significant amount of organic waste from different activities. Dining facilities (DFACs), commissaries and restaurants generate pre-consumer and post consumer food waste that currently goes to the landfill. Also during grounds maintenance a significant amount of yard waste is generated. Fort Leonard Wood's newest DFACs use a pulper system to remove the liquids from their food waste (Figure 54). After de-watering the waste in the pulper the food is disposed in the regular waste stream and goes to the landfill.

Figure 54. Food dewatering at Fort Leonard Wood DFAC.

Dining facilities produce a great amount of food waste for numerous reasons:

Pre-Consumer

- Dining facility kitchens, like many restaurants and food operators, throw away inedible (for humans) food scraps, such as banana peels, bones, and egg shells, without considering recycling or reusing them.
- DFACs may work under the assumption that every soldier will attend each meal, in turn causing them to overprepare meals, when, in reality, many soldiers can be called to duty and others may choose to go somewhere else for a meal.

Post-Consumer

- Soldiers may, at times, overestimate their hunger and pile on their plate more food than they can consume, causing them to throw the rest in the trash.
- The amount of time that soldiers are given to eat can, at times, be insufficient to finish their meals, subsequently forcing them to throw away a great deal of what is on their plates.

Figure 55. Fort Leonard Wood DPW's current compost site.

Currently Fort Leonard Wood's composting operation is very limited (Figure 55), all the organic waste generated on post could be diverted more efficiently and in a greater degree by utilizing one of the following methods presented below:

4.4.4.3 Open windrow Composting

Windrow composting is an open air composting approach in which the compost material is laid out in the open, and periodically turned or physically mixed to aerate the material (Haug 1993, Rynk and Sailus 1992). The compost is typically set up in elongated, triangular shaped piles, which allows for easy access and turning (Figure 56). While there are specialized machines made specifically for turning windrows less expensive options exist with soil or earth moving equipment, including agricultural tractors, bulldozers, and skip loaders.

Figure 56. Windrow composting.

Windrow composting is generally considered the simplest approach to large scale composting. It is easy to implement, requires very little equipment beyond what is needed for turning the windrows, and is generally very effective. Because the material is turned, it is easy to mix in amendments and modify the process after operation begins.

Of all composting options, windrow composting generally has the greatest space requirements (Figure 57), as windrows can be long and there must be enough area to accommodate them. In addition, the turning process can result in periodic release of high odors.

Figure 57. Windrow composting requires a large area.

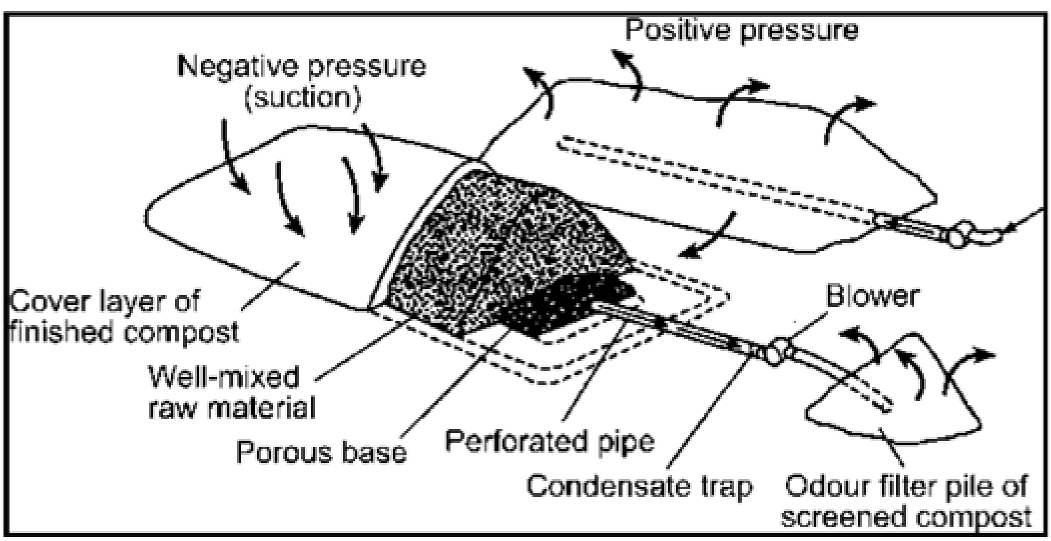
Windrow composting is very commonly performed on farms because space is typically not an issue, odors not a major problem, and farms already have the necessary equipment for the operation.

4.4.4.4 Static pile composting

In a static pile, the compost material is not physically turned. Rather, air is circulated within the pile (Rynk and Sailus 1992). This can be accomplished passively in some cases, relying on the heat differential within the pile to create the air currents. However, in most cases, air movement is forced via a vacuum or positive pressure through a piping system to insure good air-flow through the pile.

Figure 58 is a schematic of a typical forced air pile system. Piping is used to distribute air through the pile, which can be either drawn in by a vacuum system, or forced in using a blower (most blowers can be attached to work either in a vacuum or forced air mode). The pile is covered by a layer of finished compost which absorbs and degrades odors. In a vacuum operation, a simple air pollution control devise can be used to treat the gases - a compost biofilter usually works well.

Figure 58. Schematic of static pile composting.



Static piles are somewhat more complex in terms of set up than windrows. Like windrow composting, equipment is needed to move the compost materials. In addition, piping is typically placed within the pile and a blower/vacuum is attached to the piping. Designing and installing the piping system is more complex than simply turning the pile. Once a static pile is set up, it is not easy to make changes to its operation.

However, static piles are not moved once they are set up, so the operation requires less space (it is possible to turn piles in place with modern windrow turners, but these also require space to operate). Without turning, it is also possible to make the piles higher, further saving space. It is easier to set up a static pile operation so it remains covered. And without turning, it is usually easier to control odors. Joint Base Lewis McCord (JBLM) uses a forced air static system for their large composting operation (Figure 59).

Figure 59. Forced air static pile at JBLM.

4.4.4.5 In-vessel composting

In-vessel systems can best be describe as enclosed reactors (Donahue et al. 1998, USEPA 2000, Kim et al. 2008, Bonhotal et al. 2011). These enclosed reactors allow for more effective aeration and temperature control than other systems, resulting in faster composting times. These systems also have a smaller footprint, are closed to weather and can provide complete odor control. Furthermore, their operation can be semi-automated, allowing for minimal staffing needs.

While open systems like windrows and static piles are batch systems, usually requiring that composting operations occur in stages, closed systems are continuous flow, in which feedstocks can be added as they are received. This is particularly attractive with putrescent materials, like food, dead animals and sludge. A mobile, in-vessel composting reactor was recently demonstrated at Joint Base Myer-Henderson Hall (JBMHH) (Keysar et al. 2013, NDCEE 2013a, 2013b). This system (Figure 60), which would be suitable for to treat food and related wastes of 250 people (Keysar et al. 2013), had an estimated cost of $90,000 (Keysar, E., Sustainability Analyist, Countercurrent Technology Corporation. Personal Communication).

Figure 60. Mobile, in-vessel composting reactor at JBMHH.

Though often more efficient than open systems, closed systems can be more expensive. Though there are simple closed systems available on the market, these may have only marginal benefits as compared to the open approaches described above. Generally, a closed system reactor is sized for a specific range of loading. Changes to the amount of compost a specific reactor is to handle can often require the purchase of another reactor as compared to an open system where the solution is simply to begin another pile/windrow.

- space requirements
- throughput
- optimum material mix, etc.
- equipment needed
- generic diagram

4.5 Participation in the EPA Food Recovery Challenge

In 2012, U.S. EPA announced a new initiative, the Food Recovery Challenge, encouraging restaurants, retailers, venues, etc. to "commit to reducing food waste reaching landfills through prevention, donation, composting and/or anaerobic digestion" (epa.gov/foodrecoverychallenge). Military installations, which produce a considerable amount of food waste annually, could participate in the Food Recovery Challenge to save money and energy, mitigate the harmful effects of the decomposition of food waste on the environment, and help solve the hunger crisis in America. Military base participation in EPA's Food Recovery Challenge will bring the U.S. Army closer to achieving both Net Zero Waste and Net Zero Energy.

4.5.1 Participation in the Food Recovery Challenge:

There are three main parts of the Food Recovery Challenge: prevention, donation, and recycling. Participants must increase their output in either one specific part of recovery, or in all three. In order to participate in the challenge, the installation must sign up through WasteWise and enter their baseline data into the site's tracker. Following the sign-up, the installation should set a yearly goal, such as a five percent increase in at least one of the three food diversion tactics, and begin tracking their waste accumulation (epa.gov/foodrecoverychallenge). At the end of each year, the installation can compare the amounts of waste and analyze their progress.

Strategies for Food Diversion

4.5.1.1 Prevention

- Educate and train kitchen workers on food waste and food waste diversion
- Reduce prep waste and improperly cooked food
- Consider secondary uses for foods (e.g. leftover bread can become croutons, sour milk can become cottage cheese, etc.)
- Ensure proper storage techniques to reduce spoilage
- Modify menu to increase customer satisfaction and decrease the preparation of undesirable and unwanted food
- Encourage community members to take only as much as they can consume

4.5.1.2 Donation

- Donate edible leftovers to food pantries, food banks, and rescue programs, as well as shelters and youth groups.
- Donate food scraps and discards to feed livestock

4.5.1.3 Recycling

- Create soil amendment and fertilizer by composting organic materials in food waste
- Use the process of gasification in order to create syngas (hydrogen, carbon dioxide, and carbon monoxide) to be used as fuel
- Implement anaerobic digestion in order to obtain biogas (methane and carbon dioxide) to be used as fuel

4.5.2 Successful methods

Through various methods and programs, the practice of food waste diversion has been shown to have beneficial economic, environmental, and social benefits. Following are examples of successful food waste diversion actions.

4.5.2.1 Composting and anaerobic digestion

Humboldt State University (HSU) partnered with Humboldt Waste Management Authority as one of the waste authority's early adopters of their anaerobic digestion project. They have been developing their anaerobic digester and are currently assisted by HSU in composting the campus' food waste (Scott-Goforth). HSU has recycled, composted, reused, donated, or re-sold 1,034.7 tons of food since beginning the program (Humboldt State University Scorecard).

4.5.2.2 Food donation

The Food Recovery Network (FRN), started in 2010, recovers surplus perishable food from college campuses and surrounding communities that would otherwise go to waste and donates it to people in need (Tucker). The FRN now has 18 chapters in colleges and universities around the U.S.

Over three years, the FRN has salvaged 166, 354 pounds of food, the equivalent of approximately 130,000 meals (Food Recovery Network | Fighting Waste, Feeding People).

4.5.2.3 Composting

In 2012, Joint Base Lewis-McChord started collecting food waste from Army and Air Force Exchange Service restaurants, unit dining facilities, child care centers, and other facilities and delivering it to a composting facility. The military base was able to compost a total of 670 tons of food waste. Additionally, the base saved $300,000 in disposal costs and tipping fees, which was subsequently put towards the base's recycling and its programs for family, morale, welfare, and recreation (Environmental Leader 2013).

4.5.2.4 Source reduction, donation, composting

Hannaford Supermarkets began using WasteWise (EPA's first campaign to decrease waste) in 2010, later joining the Food Recovery Challenge, an initiative of WasteWise, as well. The supermarket company worked with a computer-assisted ordering program to make better sales predictions and inventory checks. This led to more accurate ordering with a reduction in duplication and excesses.

In 2010, Hannaford Supermarkets donated 3,376 tons of food to food banks, soup kitchens, and shelters. Additionally, Hannaford Supermarkets practiced composting, and in 2010, they recycled 67.29% of their total waste for that year.

4.5.2.5 Alternatives for compost application to training lands

The Army owns almost 5 million hectares (ha) of land in the United States, including 73 installations with greater than 4,000 ha each, that routinely require rehabilitation and maintenance to support training activities (DOD, 2001). These lands are often highly eroded and incur significant losses of topsoil, organic matter, and nutrients, and are prone to invasion by exotic plant species, leading to further ecological degradation. Consequently, the Army is required by law to control water and air pollution, maintain ecosystem sustainability, protect native biological diversity, and control the spread of exotic species on its training lands. As such, the Army could derive significant benefits from utilization of its own organic, composted wastes to aid in management of its training lands.

The benefits of applying compost to soils that are very sandy, lack organic matter, have poor water holding capacity, and/or are highly eroded or compacted are well known. Application rates as low as 10-15 tons per acre (about 0.25 inches thick) have been shown to significantly increase organic matter content in sandy soils (Torbert et al., 2007; Zhang et al., 1997), with the benefits often carrying over into subsequent years following one initial application (Mamo et al., 1998; Watts et al., 2012a; Watts et al., 2012b). Any increase in organic matter content improves water holding capacity and the moisture release dynamics of soils (Turner et al., 1994; Giusquiani et al., 1995), thereby supporting more desirable plant communities (Watts et al., 2012a). Military maneuver training frequently results in heavily compacted soils and compost applications nearly always decrease bulk density (Turner et al., 1994; Giusquiani et al., 1995; Pagliai and Vittori-Antisari, 1993), thereby minimizing erosion risk and improving water infiltration, porosity, and storage for plant use as the growing season progresses (Zhang et al., 1997).

On highly disturbed areas, such as bivouac sites, drop zones and maneuver areas, the soil usually lacks sufficient organic matter to support the necessary vegetative cover required to control erosion. This is frequently one of the main reasons for using composts or other organic materials on training lands. Disturbed military training and testing lands are almost always reseeded with perennial native vegetation, mostly warm season grass species [big bluestem (Andropogon gerardii Vitman), indiangrass (Sorghastrum nutans (L.) Nash), switchgrass (Panicum virgatum L.), little bluestem (Schizachyrium scoparium L.), and Virginia wildrye (Elymus virginicus L.]. These species are used abundantly in reclamation as they develop extensive root systems that penetrate deep into soils, providing a very effective safeguard against erosion (Drake, 1983). Over the long term, this vegetation is most effective at mitigating erosion and providing suitable wildlife habitat, but is difficult to establish in the short term because these species are slow growing and susceptible to competition with weedy plant species (Paschke et al., 2000; Wilson and Gerry, 1995; McLendon and Redente, 1992). Because native perennial vegetation is adapted to nutrient poor soils, oversupplying nutrients in the form of purchased fertilizers is detrimental to them and often results in failure (Launchbaugh et al., 1962; Jung et al., 1988; Wilson and Gerry, 1995; Skeel and Gibson, 1996; Warnes and Newell, 1998; Levy et al., 1999; Brejda, 2000). Adequate soil restoration often requires significant quantities of organic matter, but locating suitable sources is difficult and expensive. Further, many sources are unsuitable, as they have high N concentrations that encourage weed growth. Therefore, the carbon:nitrogen (C:N) ratio of the material is important in determining suitability. Poultry litter, biosolids, and manures have C:N ratios less than 30, which results in an oversupply of N that encourages weed growth, making them less desirable for rehabilitating damaged training areas. Other organic matter sources with higher C:N ratios, such as wood wastes (Morgan, 1994; Zink and Allen, 1998; Reever Morghan and Seastedt, 1999; Alpert and Maron, 2000; Blumenthal et al., 2003), compost derived from landscape and wood wastes (Mamo et al, 1998; Busby et al., 2007), processed municipal solid waste (Busby et al., 2006; Busby et al., 2007; Torbert et al., 2007), and sucrose (McLendon and Redente, 1992; Morgan, 1994; Reever Morghan and Seastedt, 1999; Paschke etal., 2000; Blumenthal et al., 2003) can immobilize enough N following land application to allow native vegetation to dominate reseeded sites.

4.5.3 Application rates and techniques

Rehabilitating degraded military training and testing sites where soils typically lack organic matter and favorable physical and chemical properties conducive to establishing and supporting perennial plant communities, requires significant inputs of organic amendments to improve the probability for success and sustainable future use. Minimum compost application rates should be in the range of 10 to 15 tons per acre which translates to a layer about 0.25 inches deep over the entire acre (McConnell et al., 1993). A review of rates used in experimental studies suggest that applications of finished compost between 10 and 30 tons per acre provide observable improvements in soil physical and chemical properties without significant phytotoxic effects (McConnell et al., 1993). Application rates for sandy soils can be doubled without significant concern for negative impacts (Duggan and Wiles, 1976; McConnell et al., 1993; Busby et al., 2006; Watts et al., 2012a,b). Application rates beyond 80 to 100 tons per acre should be split and should always be planned based on a soil and compost nutrient and heavy metal analyses to make sure that it is safe to apply compost at those rates. Studies by Watts et al. (2012a) and Mamo et al. (1998) have indicated that the benefits of a single heavy application rate can still be observed five years after the initial application.

Because most compost applications on degraded training ranges and maneuver areas are usually followed by some type of revegetation effort, it is important to make sure the compost is evenly applied and subsequently incorporated before seeding perennial grass species. This is most effectively accomplished with a commercial manure spreader, however, dump trucks or front end loaders can also be utilized. Using the 0.25 inch compost depth as a guide equivalent to a rate of 10-15 tons per acre, calibrate the spreading equipment to achieve the desired application rate, recognizing that some variability in rate across the area to be treated is perfectly acceptable. After the compost has been spread, it should be incorporated into the soil using a disk plow if possible to a depth of 4-6 inches. This provides the best possible seedbed for subsequently seeding grasses and minimizes the probability that the compost will be removed from the site via wind or water erosion.

Successful results from the application of compost have been achieved at several different types of Army training ranges. These have included:

1. Maneuver ranges at Fort Benning, GA, where several rates of compost were applied to highly degraded sites followed by disking and reseeding with native grasses. Application rates up to 64 tons/acre resulted in significantly enhanced plant cover and biomass production when compared to sites that received no compost (Busby et al. 2006). Plant cover and biomass differences were still significantly higher five years following the initial application (Figure 61) (Watts et al., 2012a,b).
2. Small arms ranges at Fort Benning, GA, where compost mixed with native grass seed was placed around pop-up target berms to enhance water holding capacity, minimize bullet impact pocket development, and encourage vegetation re-establishment and development (Figure 62).

Figure 61. Plant cover at Fort Benning, GA, one year after compost applications at rates ranging from 0 to 64 tons/acre.

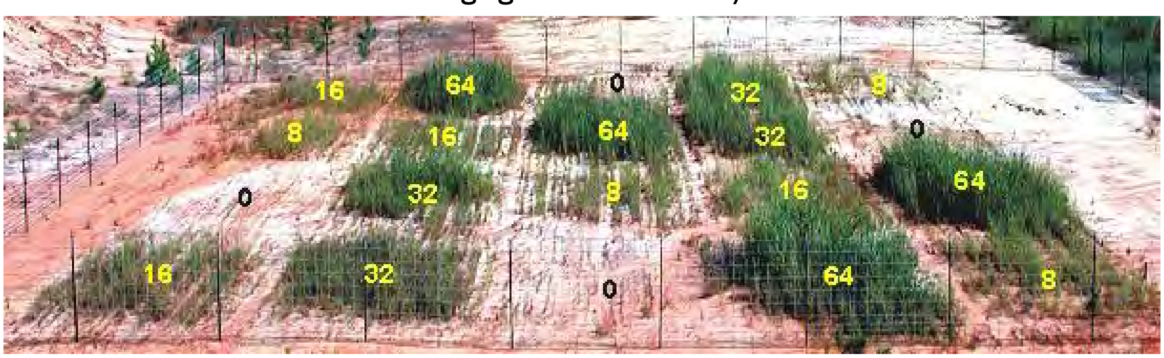


Figure 62. Small arms range pop-up target berm at Fort Benning, GA, showing development of bullet impact pockets before and after compost application.

9. Digital multi-purpose tank firing point and blast mat at Fort Drum, NY, where compost was utilized to encourage vegetation establishment and stabilize blast mat footing (Figure 63).

Figure 63. Firing point blast mat area at Fort Drum, NY, before and after compost application to encourage vegetation establishment and promote slope stabilization.

10. Reconfigurable convoy berms at Camp Atterbury, IN, were constructed using compost to provide for convoy and IED training scenarios. After training exercises were completed, compost berms were spread across the training area and revegetated in conjunction with Integrated Training Area Maintenance (ITAM) activities.

4.5.3.1 Expansion of C&D Recycling Program

Briefly, deconstructing buildings holds the greatest potential for reducing waste where the construction type lends itself to disassembly and recovering materials intact. Recycling also holds potential for beneficial use of materials as feedstock to some other material production. Up to 90 % of a building's mass can be diverted from landfill disposal through reusing and recycling materials, if such a strategy is incorporated into the building removal strategy.

Six alternatives are proposed to reduce the C&D component of Fort Leonard Wood's solid waste stream.

4.6 Recover wood from WWII-era buildings for reuse

ERDC-CERL surveyed three buildings to be demolished in FY14 and determined that it is quite feasible to deconstruct these buildings for the purpose of recovering wood materials for reuse. These buildings included 2352 Laundry facility, 2565 General Storage, and 2314 General Purpose Warehouse. It was estimated over 300,000 board feet (BF) of lumber material could be recovered from these buildings and reused, which would divert roughly 400 tons of debris from landfill disposal. The survey is included as Appendix D. Since that survey was conducted, a WWII-era Chapel and eight additional WWII-era wood buildings have been programmed for demolition in FY14, totaling an additional 34,000 square feet of building. From these buildings roughly 136,000 BF of lumber could be recovered for reuse, which would divert roughly 170 more tons of debris from landfill disposal, or roughly 570 tons in total if all wood framed buildings on the FY14 demolition list were deconstructed and the lumber salvaged for reuse.

These buildings will be demolished under the Army's Facility Reduction Program (FRP), administered by the Corps of Engineers Huntsville Engineering and Support Center (CEHNC). The FRP maintains Multiple Award Task Order Contracts (MATOC) for demolition. Multiple contractors are under a Task Order Contract, and bid competitively on a Task-by-Task basis. Thus, several MATOC contractors will bid for removing these buildings at Fort Leonard Wood.

Removing these buildings under the FRP creates challenges in that the Task will be awarded on a low-bid basis. No recognition of the qualifications and experience necessary to efficiently and economically remove large wood buildings can be incorporated into the award basis. The MATOC contractors are proficient at demolishing buildings, and often recycling metals and masonry concrete rubble. They may not be proficient at salvage. However, it also creates opportunities. The opportunity exists to introduce the demolition contractors, as the potential prime contractors, to other specialty contractors and lumber salvagers who do possess the specialty skills and experience to recover lumber for reuse. In this fashion, the demolition contractor can perform the services for which they are most qualified, while the deconstruction subcontractor performs the service they for which they are most efficient and economical. This arrangement worked extremely well at Joint Base Lewis McChord where the MATOC contractor specializing in environmental abatement and demolition subcontracted with a local salvage contractor for a Task to remove WWII-era buildings. This collaborative venture was awarded the Task as the low bidder, while also diverting over 90% of the buildings materials from landfill disposal.

Several issues must be addressed in order to ensure the WWII-era wood buildings are removed in an efficient and economical manner, while salvaging the majority of wood materials for reuse. These are as follows. ERDC-CERL's experience indicates deconstructing WWII-era buildings can be accomplished competitively with conventional demolition. Compared to demolition estimates, actual deconstruction costs ranged between 25% lower to 8% higher. The efficiency, and therefore the economy, of deconstructing buildings and recovering materials for reuse depend almost totally on the capabilities and experience of the contractor. "Hybrid" practices are emerging whereby construction equipment is used to remove large sections of the building for manual disassembly on the ground. This reduces labor expense, enables work to be performed more quickly and more safely on the ground, and improves material management. FRP bidders would do well to become acquainted with deconstruction contractors who are conversant in these methods, and can thus reduce uncertainty (and contingency factor) in their bids.

4.6.1.1 Consult existing references

The following references are available for FRP and Fort Leonard Wood personnel to consult, and should contribute to successful reuse of WWII-era building materials.

Whole Building Design Guide Resource Page: *Construction Waste Management* (see http://www.wbdg/resources/cwmgnt.php. Guidance and resources for reducing both construction and demolition waste is provided.

Whole Building Design Guide Resource Page: *Construction Waste Management Database* (see http://www.wbdg.org/tools/cwm.php. This database provides sources for companies that haul, collect, and process recyclable materials from construction and demolition projects.

PTWB 1-200-23 *Guidance for the Reduction of Construction and Demoliton Waste through Reuse and Recycling* (see http://www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_1_23.pdf) . There are example approaches, contract provisions, and specifications offered in this document. This PWTB is currently under revision, primarily to update references and add some recent information. The basic information is still valid.

PWTB 1-200-120 *Opportunities to Increase Construction and Demolition Waste Diversion* (see http://www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_1_23.pdf) . Lessons learned and improvements to building removal practices are offered in this document.

4.6.1.2 Describe this project to communicate expectations to all

The FRP is reluctant to use the term “deconstruction” because of perceived connotations about added expense and time. The terms “demolition” and “deconstruction” need not be positioned as polar opposites. Deconstruction is one method of demolition. In practice, deconstruction, salvage, demolition, and recycling can all be applied when removing a building.

Regardless of the terminology used, Fort Leonard Wood’s objectives are to remove the building in an efficient, economical, and safe fashion while recovering as much of the building’s materials for reuse as practical and minimizing landfill disposal. Thus, “demolition” must not imply to the contractor they should remove the building by destructive means without regard to material recovery and reuse.

Note that UFGS 02 41 00 [Demolition] [and] [Deconstruction] addresses both methods of building removal. Therefore, the term “deconstruction” is not unknown to Army or other Federal Agencies. (see http://www.wbdg.org/ccb/DOD/UFGS/UFGS%2002%2041%2000.pdf).

4.6.1.3 Perform outreach to the deconstruction material reuse industries

In order to meet the customer's expectations, the contractor must apply to the project the necessary services to remove the building(s) efficiently and economically, in a safe manner, extracting as much useable material as practical. If that expertise does not reside in-house with the FRP MATOC contractors, services are available in the region (Missouri, Iowa, Illinois) to supplement the contractor's capabilities. These include deconstruction services, building materials brokers, recovered building materials resale businesses, and training and consulting services to provide project planning and execution guidance. As of the writing of this report, the following have expressed interest in participating in this project, or have been referred as possessing the capabilities to participate in the project in some capacity.

- Al Wolfe Demoliton (MO)
- American Antique Wood (MO)
- Brandenburg Construction LTD (IA)
- Dickens Demoliton (MO)
- Elmwood Reclaimed Lumber & Timber (MO)
- Green Demoliton, LLC (MO)
- Gronen Restoration (IA)
- Houston Excavation (MO)
- Habitat for Humanity Deconstruction and ReStore, Kansas City (MO)
- Habitat for Humanity – St. Louis Deconstruction Services (MO)
- J. Huffman Lumber Salvage (IL)
- Kansas City Habitat for Humanity ReStore (MO)
- Lee Farms Demoliton (IL)
- Metropolitan Energy Center/Green Up: Reclaim KC (KA)
- Midwest Reclaimed Lumber and Salvage Co. (IL)
- Perhat Lumber (MO)
- Planet Reuse (MO, material brokers)
- Resource St. Louis (MO, material exchange)
- Reuse Consultants (WA)
- SCDI Deconstruction (IA)
- Sharkey's Building Wrecking (IA)
- Ted Strakus Construction (IA)
- The Reuse People of America (CA & MO)

- Vorwald Log & Lumber (IA)

These capabilities include dismantling buildings and taking the lumber for resale or manufacture into other wood products, retail sale of salvaged lumber, marketing recovered building materials, and consulting demolition and deconstruction contractors.

Conducting an on-site “workshop” has proven very effective in the past. The purpose is to bring prospective contractors and other necessary services together in one place, at one time. While the Government cannot assign subcontractors to prime contractors, they can provide a forum for information exchange. Doing so also provides an opportunity to clarify Fort Leonard Wood’s expectations for the project to all prospective participants. If a pre-bid or pre-proposal meeting or job walk is held, this would be the ideal opportunity time to bring the prospective participants together.

Previous deconstruction experience suggests outlets for many materials can also be found on-post. Scrap lumber, windows, doors and landscape materials have frequently been requested by troop units for self-help projects or construction of training aids. A survey of other Fort Leonard Wood offices and agencies is suggested as identifying on-post reuse opportunities.

Special outreach efforts for recycling metals, concrete, and scrap wood should not be necessary as these practices are common within the demolition industry. The Army’s position that incineration does not count toward diversion, even if applied to waste-to-energy bio purposes, must be clarified to contractors and C&D recyclers.

4.6.1.4 Define deconstruction tasks within one MATOC Task

If possible, separate the demolition tasks (for which material recovery is an objective) from the other study or survey, abatement, and demolition (by wrecking) tasks for a 30-some building demolition task has advantages. Doing so places 100% of the contractor’s attention on the deconstruction tasks. It avoids the risk of a contractor under-performing because deconstruction represents only a small part of a larger demolition contract’s dollar value.

4.6.1.5 Describe materials available within the buildings to be deconstructed

Description of the types and quantities materials available for recovery and reuse in the Scope serves two purposes. It informs bidders of the potential value of the building's materials, and alerts bidders that the Army is aware of the potential value. Thus, bidders are expected to take into account material value when developing their bid. In Buildings 2352, 2565, and 2352, there are roughly 300,000 Board Feet of lumber and timber available. The addition of a Chapel to the list increases this potential resource even further. This figure does not include blocking, cripples, braces, and other members under 6 feet long. There is also in excess of 20 tons of metals in building 2352. This information should be provided as information only to the prospective bidders and is not intended to represent a detailed quantity take-off.

4.6.1.6 Ensure material ownership is titled to the contractor

As is common practice, the demolition contractor is deeded ownership of all materials, with the exception of any the Government desires to retain. The Task Order should include a provision that all revenue from recovering and recycling materials and cost avoidance through diverting materials from landfill disposal accrues to the contractor. All expenses in landfill disposal are likewise borne by the contractor. Otherwise, recovering material creates an expense for the contractor without compensation.

4.6.1.7 Require qualifications as part of the bid requirements

The procurement method for this Task will be via Competitive Bid. As the lowest responsible bid will be awarded the Task Order, The Task Order should include a bidder qualification requirement as an element of responsibility. This should include demonstrated capabilities and experience in removing buildings with the purpose of recovering materials for reuse. Qualifications include example projects, materials recovered and recovery rates, and disposition of the materials (i.e. knowledge of outlets and markets). Other services retained by the contractor (excavation, recycling, wrecking, hauling, etc) should likewise display capabilities and experience within the scope of their services.

4.6.1.8 Consider including options within the bid schedule

One method of increasing diversion rates is to include bid options in the bid schedule for successively higher diversion rates above the required minimum of 58%. Where materials recovery for reuse is the preference, the bid options can incorporate a reuse rate. If a Best Value solicitation will not be offered, bid options may be the next best method to balance performance and price.

4.6.1.9 Require the contractor to develop and submit a C&D waste management/reduction plan

A C&D Waste Management Plan should be standard with any construction or demolition contract. Beyond compliance with waste disposal regulations, however, this Plan should also address building removal methods, materials recycled and recovered for reuse, debris materials, subcontractors or services applied, material outlets or markets applied, and recycling and disposal facilities. The Plan should also include performance monitoring, recording, and reporting processes on the part of the contractor. UFGS 01 74 19 Construction and Demolition Waste Management, can serve as a model to be tailored for the specific project (see http://www.wbdg.org/ccb/DOD/UFGS/UFGS%2001%2074%2019.pdf).

This Plan should be required as a Submittal, and reviewed and approved by the Government prior to issuing a Notice to Proceed. If it is apparent the contractor is diligently applying the resources available to them, the plan is reasonable given the project's requirements and conditions, and will achieve the highest reuse and diversion rate practical, then the Government approves it and issues the NTP. If it is apparent the contractor is underutilizing available resources, is questionable in the contractor's ability to execute, or otherwise suggests satisfactory results may not be forthcoming, the Government can return the Plan for revision before issuing the NTP.

Once the Plan is approved, it becomes part of the Contract and is applied (i.e. enforced) as such.

4.6.1.10 Establish waste diversion recording / reporting requirements in the task order description

C&D materials recycling and reuse performance must be monitored, recorded, and reported similar to safety, regulatory compliance, and other topics throughout the project's duration.

The MILCON RFP cites a requirement to report C&D diversion performance every 30 days. In the case of the Fort Leonard Wood demolition project, this is too long a period of time between reports. A building can be gone and the site restored in that time. The frequency of reporting should allow for the evaluation and readjustment to address any performance issues occurring during the project's execution. Otherwise, reporting will always be after-the-fact cannot contribute to improving performance.

Reporting C&D diversion performance at weekly progress meetings is advised.

Include C&D diversion processes in quality control / quality assurance

Monitoring and reporting C&D materials reuse and diversion performance should be integrated within the QC/QA requirements.

Ensure the demolition / deconstruction task order description / specifications are consistent with the building material recovery & reuse objectives of the project

The demolition specification language may be similar to a conventional demolition project, such as, UFGS 02 41 00 [Demolition] [and] [Deconstruction] (http://www.wbdg.org/ccb/DOD/UFGS/UFGS%2002%2041%2000.pdf).. Note that this specification must be tailored to the specific Fort Leonard Wood and FRP project conditions. All occupational safety requirements must be observed regardless of the methods used to remove the building. This includes exposure to lead. Note that, in previous Army deconstruction projects, personal and ambient monitoring have always resulted in a negative assessment, and therefore respiratory protection can be reduced. However, good housekeeping practices to limit the spread of lead-based paint chips around the building, by individuals, and around the site and dust must be observed throughout the project.

Waste diversion criteria must be included in the Task Order description / specifications. As a minimum, a 58% diversion rate must be specified for FY14 projects. The expectation that the majority of lumber is expected to be recovered in a reusable condition must be reflected with this criterion. Exterior siding and other wood materials that are lead-based painted can be excluded. Recycling of metals is assumed, although there are mechanical components that are still serviceable and could be recovered for reuse.

A lumber recovery rate of about 75% is usually realistic, accounting for breakage, deterioration, short pieces, etc. However, it may be more prudent to not place a minimum recovery-for-reuse percentage on any individual material, and allow the 58% overall criterion to prevail. In this case, a higher overall diversion requirement would be entirely reasonable. Lumber will constitute the majority of the building's mass, as the foundation and slab will not be removed, and are not counted as either debris or diversion. Recycling wood materials into bio-fuel will not count as diversion. Therefore, the contractor will be compelled to secure reuse outlets for the reusable lumber materials. It is suggested, therefore, that the contractor's C&D Waste Management/Reduction Plan, as approved by the Government, dictate the rate of lumber recovery for reuse to be applied as the contract requirement. If, however diversion rate desired, a rate of 65% of the building materials in-place (not including foundations and floor slabs remaining in place) should be achievable. Where foundations will be removed, rates of 75% and higher should be achievable. . As discussed above, bid options for diversion rates higher than 58% can also be incorporated into the bid schedule.

At present, there is no Federal level regulation that prohibits the transfer of materials with lead-based paint. The contractor should be entitled to take lead-based painted materials as long as they will handle and process these materials consistent with occupational and consumer safety standards. It will, however be prudent to include disclosure of the presence of lead in the contract documents, and to require a disclosure when selling or transferring LBP'd material to third parties. Disclosure language and reference to other HUD/EPA guides about exposure to lead in homes is included in PWTB 200-1-23, referenced above.

It may be useful to the contractor to be able to process and hold recovered materials at Fort Leonard Wood prior to transporting them to outlets. If Fort Leonard Wood has any vacant buildings that could possibly be useful to the contractor while the last building is being demolished, it is suggested Fort Leonard Wood makes this opportunity available to the contractor. The appropriate time limits, condition of the building upon completion, and similar requirements, must be included in this provision.

Obtain all final C&D waste diversion documentation as part of project close-out process

Project close-out should proceed as with any other demolition project. Ensure all final diversion and disposal documentation is obtained and included in the project file. Diversion data (in addition to all other relevant documentation) must be provided to the DPW engineering branch and Solid Waste Manager. Ensure the Fort Leonard Wood Environmental Division personnel responsible for entering data into the SWAR are provided with the required information.

Be receptive to publicity/press coverage

Past "deconstruction" projects have typically drawn favorable attention from the public. While not a contract requirement, project personnel should be open to positive publicity and cooperation with media.

4.7 Recycle C&D wood from WWII-Era buildings

Comingled C&D debris can be hauled to a C&D recycling facility. This is common practice in both commercial and Army markets. Once at the recycling facility, concrete and masonry materials are removed from the pile and the remaining debris is crushed, conveyed through a "pick line," and sorted. The materials of greatest value are typically metals, paper and cardboard, plastics, and wood. After sorting, wood debris is shredded and sold. The vast majority of C&D wood is processed and sold as bio mass fuel.

Sending comingled debris to a C&D recycler should be no different from a contractor's perspective than sending debris to a landfill, with a possible exception of location and hauling distance. C&D recyclers may offer slightly lower tipping fees than landfills, although fee structures would have to be confirmed on a project-by-project basis.

In order to count C&D wood as being recycled, the FRP must ensure that the recycling facility markets the processed wood for end uses other than bio mass, such as mulch or wood chips used in engineered wood products.

Wood materials contaminated with lead based paint, primarily exterior wood siding, cannot be sent to a C&D recycler. These materials will not count as part of the non-hazardous debris stream, so there will be no effect on the diversion calculation.

It would be very difficult, if not impossible, to track wood debris from Fort Leonard Wood buildings, alone, once they are deposited at a C&D recycler. The recycler would, however, be able to identify the secondary processors to whom they sell their processed wood. This is the method by which the CDRA audits recyclers for certification under their Certification of Real Rates (CORR) program. This auditing includes the input of a material (C&D wood, in this case), the destinations of the processed materials, and the end use of the processed materials, all by type and quantity, over a year's time. Thus, it will be evident whether C&D wood materials deposited with any individual recycler are processed for bio mass fuel or recycled into feedstock for some other end use. The FRP should include in the contract a requirement for a C&D recycler to identify their outlets for C&D wood. The CORR process can serve as a model for the FRP contract requirements.

- Eco Recycling
- Hutchens Construction Company
- Millstone Bangert, Inc.
- Peerless Resource Recovery
- R2R, LLC
- Simpson Materials Company
- Swift Recycling

While the preference should be to reuse wood materials that are reusable, there will be a quantity of wood from these buildings that are unsuited for reuse because of member length, damage, or contamination. Therefore, recycling some wood will still be necessary. Roughly 190 tons of wood materials from WWII buildings programmed for FY14 demolition may be unsuitable for reuse. If no end use for C&D wood other than bio fuel can be found, use as bio fuel is still preferred to landfill disposal, even though that quantity cannot be counted toward diversion.

4.8 Recycle wood from WWII-era buildings on post

As an alternative to having C&D wood debris hauled off site for recycling or processing as bio mass fuel, Fort Leonard Wood can process wood debris on-post for its own uses; erosion control, mulch, ground cover, or bio mass fuel. Using bio mass as fuel will not count as C&D waste diversion, however it can count toward net-zero energy goals.

According to a wood waste processing model developed for ERDC-CERL by MOCA Systems, chipping wood waste will cost roughly $100/ton (roughly 3 CY) to produce on-site. This model is based on the government purchasing and owning the equipment, operating it on contract, and producing 1,000 tons of chips per year. This yearly throughput is roughly five times the quantity of wood materials could not otherwise be reused from the WWII-era wood buildings to be demolished in FY14 that. It is reasonable to assume other sources of wood waste would be processed as well, so the entire cost of the wood processing would not be borne by processing C&D wood alone. Processing more wood waste per year will reduce the per-ton use. For example, processing 10,000 tons per year is estimated to cost roughly $40/ton.

Several Army installations contract for wood processing services, which avoids the initial investment in equipment. Under this scenario, the contract cost for chipping wood is roughly $5 - 10/ton.

4.9 Increase asphalt, brick, and concrete recycling rates

Throughout the period of 2010 through 2012 16,646 tons (62%) of asphalt, brick, and concrete (ABC) was recycled at Fort Leonard Wood. While this is not an insignificant diversion rate, virtually all ABC materials can be recycled. A rate closer to 90% would be expected. In fact, 96% of ABC materials were recycled in 2010, but only 45% and 43% in 2012 and 2011 respectively. Given the Army's C&D diversion calculation is based on mass, recycling ABC materials offers an opportunity to increase rates diversion significantly. At a three year average of 62%, roughly 10,000 tons of ABC materials were not diverted, which at $48/Ton, cost about $480,000 in tipping fees.

As ABC materials are being recycled from Fort Leonard Wood projects, increasing the recycling rate may be more a matter of emphasis, priority, and/or motivation than any physical or economic obstacle. MILCON , FRP, and OMA project managers must ensure that ABC materials are diverted from landfill to the greatest extent practical.

Recycling ABC materials can be accomplished in the following ways:

Comingled C&D Debris - Recycling ABC materials can be accomplished by hauling comingled C&D debris to a C&D recycling facility. There, concrete and rubble will be separated, crushed, and sold as recycled concrete aggregate (RCA) and inert fill material. This is the easiest and cheapest method of disposal from the demolition contractor's perspective. Segregating asphalt, bricks, and concrete from the debris stream may result in a slightly lower tipping fee, as the recycler will not have to sort the debris and pick out the rubble. However, it still creates an expense for hauling and tipping, and the Government does not accrue any befit from the recycler's sale of recycled asphalt and RCA. Further, the FRP contract administrators must ensure that ABC materials hauled to a C&D recycling facility are actually recycled, or what portion hauled to the recycler are actually recycled. One common application of ABC rubble is as alternate daily cover (ADC) for landfills, which does not constitute recycling by the Army's definition. The end use of ABC materials can be verified through the CDRA CORR certification or a similar auditing process.

Recycle ABC On-Post for On-Post Use - A more useful disposition of ABC materials would be to recycle on-post, for use on-post. The common application for recycled asphalt is cold patching. Common applications for recycled brick and masonry include inert fill, and sometimes engineered fill. Common applications for recycled concrete include compact base for paving, trails, erosion control, or most other applications where quarried aggregate is ordinarily used.

Several Army installations collect concrete rubble at a designated location for periodic recycling. On-post landfills are the usual locations. As Fort Leonard Wood does not have an active landfill, some location will have to be established. A half-acre area should be ample for the equipment and operation. Additional area required for rubble deposit depends on how much rubble will be generated at Fort Leonard Wood. A flat, stable surface is required, although a hardstand is not. Crushing and conveying equipment is electrically powered. However, on-site electrical power is not necessary as crushing equipment is usually powered by a diesel generator.

Fort Leonard Wood can contract with a recycling service to crush the accumulated materials on post. A quarterly basis is a common cycle. Fort Leonard Wood should survey their commands, tenants, Public Works and other on-post agencies, and assesses what types of materials are required and to what specification they must be produced. The recycling contractor will bring either portable or moveable equipment on-site, depending on the crushing requirements, and will produce the product(s) per Fort Leonard Wood's specifications. The RCA, recycled asphalt, and/or masonry rubble products will be left for Public Works and others to use until the next crushing operation is scheduled.

When crushing ABC materials on a contract basis, several cautions must be observed. The contractor performing construction or demolition will not be the contractor recycling the ABC materials. The construction or demolition contractor must, therefore, deposit the rubble in a condition that will enable recycling into a useful product. The construction or demolition specification must include the following requirements, and Quality Control/Quality Assurance provisions must ensure compliance.

The rubble must not be contaminated with other debris. Ferrous metals and reinforcing can be extracted during the crushing, but dirt, wood, plastics and other non-ferrous materials cannot. Concrete cannot be comingled with asphalt. Concrete and brick or masonry may be comingled if the subsequent use of the recycled product permits it. Otherwise, producing higher grade aggregate requires that concrete be segregated from other rubble materials.

Unreinforced concrete is the easiest to crush if individual rubble pieces are appropriately sized. The type of crushing equipment will determine the maximum size, although breaking rubble down to roughly 2 ft. by 2 ft. by 3 ft. pieces will be adequate for most equipment.

Reinforcing steel can be magnetically separated from the concrete during the crushing process. However, rebar should not protrude further than 6 in. from rubble pieces. Otherwise, tangles of rebar will form at the crusher hopper and will obstruct the crushing process.

Alternatively, the demolition contractor may leave rubble in an as-is condition. The recycling contractor, therefore, must be informed of the condition of the rubble, and that preparing it for recycling (i.e. sorting, sizing) will be their responsibility.

The advantage of contracting recycling services is that there is little, if any, added expense for the construction or demolition contractor. Fort Leonard Wood will have a source of recycled asphalt, concrete, and fill material. However, some agency at Fort Leonard will have to fund this operation.

Quarried aggregate is plentiful in the Fort Leonard Wood region. DPW personnel report aggregate costs of roughly $10/ton. A rule of thumb price for recycling concrete aggregate on-site is roughly $5/Ton, plus mobilization and demobilization costs. Roughly $4/ton can be saved by using RCA in lieu of quarried aggregate. Hauling requirements will also be reduced if materials are moved on-post, as opposed to hauling them from off-post. Throughput depends on the recycling equipment applied. A reasonable rate for most ordinary concrete recycling operations is 100 - 300 tons per running hour, or more.

Include Recycling in Construction and Demolition Contracts
Concrete and rubble can also be recycled within the scope of demolition or construction contracts. Fort Leonard Wood must promote this to the contracting agency (i.e. USACE or the FRP), who would include funding for this activity within the Program Amount or contract budget. In this way, the same party is responsible for both the demolition and recycling tasks, ensuring compatibility between these tasks and application of the appropriate recycling equipment. Where recycled aggregate can be incorporated in the new construction project, the contractor would recycle concrete to the required specification. While this incurs an expense in recycling, it avoids cost of debris hauling, tipping, and new aggregate purchase. The jobsite would have to be large enough to accommodate recycling operations and storage of the recycled aggregate until they are used in the new construction.

The contracting agency must ensure that the contractor's plan for recycling on the jobsite is viable. While the Government cannot direct the Work, the Government can review the contractor's work plan and proposed equipment and determine whether it is appropriate for the task. If there is doubt the proposed recycling plan and equipment will achieve the required results, further verification or plan revisions can be required.

If the recycled aggregate cannot be used in the new construction, it can be deposited in the location designated by Fort Leonard Wood. In this case, however, recycling is all expense and no benefit from the contractor's perspective. Fort Leonard Wood would receive recycled products, which would be paid for at the construction or demolition program's expense.

4.10 Increase metals recycling rates

The SWAR data indicates 44.62 tons of metals were diverted at Fort Leonard Wood from 2010 through 2012, which is only 0.62%, and this was all in 2012. Nothing was reported in 2010 or 2011. If this data is accurate, over 3,200 tons of metals were generated by C&D activities in 2012, but roughly 3,166 tons were not diverted from landfill disposal. In addition to paying over $152,000 for tipping, the scrap value of 3,166 tons of metals, roughly $633,000, was not accrued, assuming a value of t $200/ton for ferrous metal scrap.

It is universal practice for construction and demolition contractors to segregate metals and send them to commercial scrap metal dealers. Very little metal is deposited in landfills nowadays in commercial markets. It is unlikely Fort Leonard Wood , FRP, or USACE contractors would have ignored this money making opportunity. It is more likely metal diversion was not accurately monitored and reported to the SWAR.

This underscores the importance of accurately recording diversion data from all MILCON, FRP, and OMA construction and demolition jobsites, and transmitting this data to the appropriate DPW personnel for reporting in the SWAR. Otherwise, Fort Leonard Wood appears to fail meeting diversion goals.

Increasing metals recycling rate may be more a matter of emphasis, priority, and/or motivation than any physical or economic obstacle. Metals are undoubtedly being recycled at Fort Leonard Wood, whether recycling is recorded or not. Metals may “walk away” from construction and demolition jobsites, which still diverts them from landfill disposal. However all diversion, formal and informal, must be recorded. MILCON, FRP, and OMA project managers must ensure that metals are diverted from landfill to the greatest extent practical. Diligence in monitoring and recording at the project level, then accurate reporting in the SWAR at the DPW level required.

Preferably, the Government should accrue some economic benefit from the salvage value. The most common practice is that construction and demolition contractors incorporate salvage value into their bid development. Knowing they can accrue some value from metals, they can reduce their bids to become more competitive. Thus, the Government benefits economically by a reduced cost of services.

The Fort Leonard Wood QRP can also sell C&D metals, if this is agreeable to the QRP. This would have to be an option for construction and demolition contractors, for their convenience, as they would accrue no economic return. However, it may be more convenient to deposit metals on-post than to haul them off-post. The QRP would have to establish arrangements for delivery logistics and determine the types of metals accepted, dimensions and weights, and other parameters for the metals. These provisions would have to be incorporated into the contract documents.

C&D metals sold through the QRP can be included in Fort Leonard Wood's diversion calculation. However, this quantity must be reported through one or the other diversion avenues, not both. The QRP and DPW must determine between them how diversion should be reported.

4.11 Increase diversion of other materials

The SWAR reports 12,100 tons of "C&D other" being diverted from 2010-2012, a diversion rate of 37%. This means, 63% of "other" materials were not diverted, which would be roughly 20,600 tons. Landfill disposal of "other" materials that were not diverted cost roughly $989,000 in tipping fees.

Metals, concrete, and wood are the materials most commonly recycled; i.e. the "lowest hanging fruit."

Plastics, window glass, gypsum drywall, carpet, acoustic ceiling panels, are all recyclable. However, demolition and construction contractors frequently have difficulty finding outlets for these materials, or find it inconvenient to recycle these materials, as ABC materials and metals weigh enough to satisfy the minimum diversion requirements and there is no incentive to exceed these requirements.

Of all C&D categories, "C&D Other" represents the largest component of the C&D waste stream (32,700 tons) and the greatest quantity of materials that were not diverted from landfill disposal over the last three years (20,600 tons).

As C&D waste management is the responsibility of contractors, and the Government should not direct contractors, the Government has limited leverage over the contractor's processes. Thus, Fort Leonard Wood must encourage, or appeal to the contractor's good will to go the extra step and reduce waste beyond minimum contract compliance. Becoming knowledgeable about available reuse or recycling markets in the area and providing information should be offered as helping the contractor do their job. If the contractor is receptive, this information should be useful to them in improving diversion rates.

Review of the contractor's C&D Waste Management Plan should also indicate whether or not the contractor is taking advantage of all the reuse and recycling resources available to them. If it is evident they are not, the plan should not be approved.

The following discussion describes opportunities for diversion of "C&D Other" materials in the State of Missouri. ERDC-CERL will compile further information about resources available to Fort Leonard Wood, or their contractors, to reduce landfill disposal. Such information will include contacts, materials accepted, logistics, and implementation guidance.

4.11.1 General materials

A number of resources are available to facilitate the reuse and recycling of building materials in Missouri. They include the Missouri Recycling Association (MORA) Recycling, the Missouri Environmental Improvement and Resources Authority Midwest Materials Exchange, Planet Reuse in Kansas City, Resource St. Louis in St. Louis, and others.

Habitat for Humanity ReStores and other used building material business are also located throughout Missouri. They generally accept as donations architectural items (doors, windows, flooring, cabinets, siding, brick, block, etc), mechanical items (fans, duct accessories, some heating and cooling equipment), plumbing fixtures and equipment, and electrical fixtures and distribution components for resale and reuse. Their market is typically residential and Do-It-Yourself applications. While these items may not constitute a major portion of a building's mass, they are not insignificant either.

The Construction and Demolition Recycling Association (CDRA) Members Directory includes 6 mixed C&D recycling facilities in Missouri and an additional 16 in Arkansas and Illinois. Not all businesses will accept all materials, but among them, it is likely avenues for diversion can be found for most building materials.

4.11.2 Gypsum wall board

Clean gypsum wall board (GWB) can be recycled into new GWB, used as a soil amendment, or incorporated into compost. See http://www.drywallrecycling.org/. There are several landscape and turf management businesses in Missouri who use recycled GWB in their compost. The City of Columbia Public Works Department, Compost Facility accepts recycled GWB.

It is most common for third party processors (i.e. C&D recyclers) to transport the GWB feedstock to manufacturers or other end users. The quantity of GWB scrap from any single may not be sufficient to justify transportation to a recycling facility, or attract a recycler to operate on-post. Collecting GWB scrap can aggregated that waste stream into a greater volume should make it more attractive for recyclers. Note that GWB scrap must be kept dry. In addition to generating hydrogen sulfide gas, recyclers will generally not accept wet GWB.

Alternatively, GWB scrap can be shredded on-post and incorporated into compost. This would require Fort Leonard Wood to either purchase and operate a shredder, or to contract for shredding services.

Habitat for Humanity ReStores will generally accept whole or half sheets of clean GWB for resale.

4.11.3 Asphalt shingles

Recycling asphalt shingles has always been possible. Bitumen can be extracted from both new asphalt shingle scrap and tear-off shingle debris and incorporated into new hot mix asphalt. See http://www.shinglerecycling.org/.

However, until the early 2000's, economic feasibility was questionable. The rise in petroleum prices during that time made recycling asphalt shingles economically attractive, and an infrastructure grew to satisfy that market. Even though petroleum prices have fallen since that time, the shingle recycling industry continues be robust. The Shinglerecycling.org website (maintained by the CDRA) lists 13 businesses in Missouri, in 24 locations, who recycle asphalt shingles. CDRA also publishes the "*Recycling Tear-off Asphalt Shingles, BEST PRACTICES GUIDE.*" Other paving businesses and recyclers also recycle asphalt shingles for use in hot mix asphalt.

4.11.4 Carpet

Post consumer carpet can be recycled through several methods. Constituent materials can be extracted and recycled into new carpet, or sent to secondary processors for use in other products such as fibers, molded plastic products, and as a fuel source.

Reasonably new carpet can be reused. Carpet tiles are easily reused, as they can be applied in virtually any configuration. The Fort Leonard Wood DPW should survey tenants and other agencies on-post to determine opportunities for reusing serviceable carpet.

Carpet America Recovery Effort (CARE) is a national carpet recycling network. See http://www.carpetrecovery.org/. CARE certified collectors are located in both Kansas City and Jefferson City MO. Additional carpet recycling businesses are located in the Kansas City and St. Louis areas.

4.11.5 Plate glass

Not all recycling facilities accept window glass, although many do. Window glazing is substantially different from beverage container glass, and the two types of glass cannot be comingled. Furthermore, there are different types of window glass, which cannot be comingled to manufacture new glazing products. However, window glazing can be recycled and incorporated into other products such as fiberglass, ceramics, asphalt paving, reflective paints, and others.

There are glass recycling business in the Kansas City and St. Louis areas accept window glazing and market the cullet for remanufacturing. They will typically leave receptacles at the jobsite. If windows cannot be reused, they would have to be removed from the building and the glass broken out into the receptacles. The frame material would then be available for recycling.

4.11.6 Acoustic ceiling tiles

At present, only Armstrong World Industry accepts acoustic ceiling tiles for recycling. This was a cumbersome proposition in the past, although

Armstrong has made continuous improvements to make collection more convenient. See http://www.armstrong.com/commceilingsna/article45691.html. There are Armstrong recycling partners located in St. Louis and Kansas City. There are additional recycling partners located in all neighboring states as well. Waste Management also performs collection services for Armstrong. Collectors should be contacted to arrange receptacles or pick-ups. Full containers are preferred. Fort Leonard Wood, or construction or demolition contractors, should aggregate ceiling tiles from multiple projects to provide enough volume to fill a container.

4.12 Recommendations

After evaluating different alternatives applicable to Fort Leonard Wood and evaluating against their goals in the ISSP. The ERDC-CERL team provides the following recommendations:

- To perform a composting feasibility study that incorporates an evaluation of organic waste generation (including DFAC food waste) and selection of a composting technology for demonstration. One such composting technology category that could be demonstrated is an in-vessel system. ERDC-CERL will perform this demonstration in FY2014 through funding from PAIO.
- To consider the implementation of a comingled recycling program using facilities and resources in the Missouri area. Under PAIO funding, ERDC-CERL will develop a plan for commingled (single stream) recycling for DPW. This will include recommendations on which materials to collect together or separately to maximize diversion and revenue.
- To expand the C&D recycling program to add components of the C&D waste stream such as wood and metals. This can be done through adjusting and standardizing construction management contracts to incentivize waste diversion; and require reporting to DPW; for MILCON, OMA, and FRP projects. ERDC-CERL has funding from ASA-IEE to develop standard practices for improving CD waste reporting; this work will be shared with DPW staff.
- Consider establishing a concrete recycling site, using the concrete generation projections herein to scope it. It might be possible to coordinate Engineer School training activities at the quarry site to help process waste concrete for beneficial, on-post use. ERDC-CERL is pursuing funding options for a small scale demonstration of this idea, whereby

scrap concrete of specific dimensions might be used to augment natural habitat for the Hellbender salamander.

5 Summary

5.1 Overview

This technical report documents the results of CERL's research project to look closely at current practices and trends of energy and water use and waste generation at Fort Leonard Wood and identification of future alternatives that could bring the base closer to the ISSP Net Zero Energy, Water and Waste goals. The report uses Army data for populations, real property, energy and water use, waste generation and recycling to track Fort Leonard Wood's progress towards achieving mandated Army targets for energy reduction, water conservation, and waste reduction/diversion.

A considerable amount of effort was spent collecting and analyzing data to build the energy, water and waste baseline and base cases. Specific recommendations for achieving Net Zero Energy goals are discussed at the end of Chapter 2. Net Zero Water goal recommendations are addressed in the conclusion of Chapter 3, and Net Zero Waste recommendations are explained at the end of Chapter 4. The details provided in Chapters 2, 3 and 4 offer ideas to Fort Leonard Wood staff responsible for energy and water management, facilities design, operation and maintenance, project planning for facility reduction, renovations and repairs, and recycling or disposal.

Army funding for new construction has significantly declined, so one way to work towards achieving Net Zero Energy, Water and Waste goals is to make incremental improvements to existing infrastructure during maintenance, repairs, replacement of fixtures or major renovations. Larger, more costly projects could help Fort Leonard Wood make quicker progress towards achieving their Net Zero goals, but development of the technical specifications and economic justification takes a considerable amount of time and coordination with DPW staff.

Several projects were identified during this Net Zero Energy/Water/Waste study to help Fort Leonard Wood accomplish their Net Zero goals. CERL proposed two reimbursable projects for further development next fiscal year:

1. Provide sustainability reports, engineering analyses, technical guidance, and cost information for Fort Leonard Wood to become a Net-Zero Energy, Water and Waste Installation. The objective of this proposed project is to analyze Fort Leonard Wood sustainability reports and execute engineering and cost analyses to develop guidance, specifications and cost-benefit information for Fort Leonard Wood for net zero energy, solid waste and water actions identified in FY 2013.

2. Food and landscape waste composting: Logistics and Economics / Demonstration / Documentation of Process and Use of Finished Product for Training Range Rehabilitation. The objective of this project is to collaborate with Fort Leonard Wood DPW and Range Operations to investigate and report the logistics and economics of using an in-vessel aerobic composting system for composting food, landscape, and other high carbon waste materials. Use of a small in-vessel aerobic composting system will be demonstrated using a mixture of food wastes, landscape wastes, and other similar high carbon content waste products (classified paper, office paper) produced by Fort Leonard Wood. Parameters of the actual composting demonstration in terms of waste collection, waste processing, in-vessel siting/construction/operation, finished compost transportation and use, and material/time/labor requirements associated with each parameter will be documented. Finally, specific uses of the finished compost for rehabilitation, stabilization, maintenance, and improvement of training ranges and maneuver areas will be identified.

5.2 Recommendations

5.2.1 Better collaboration between CERL researchers and Directorate of Public Works staff

CERL researchers worked closely with several key Directorate of Public Works (DPW) stakeholders throughout this project, but since DPW staff are so busy with daily crisis management, many others were unable to attend the quarterly ISSP meetings. Attempts were made to attract more interest by offering Energy Day and Water Day events during the quarterly ISSP IPRs.

Project ideas need to be shared with key Fort Leonard Wood personnel early to get feedback on how the results can be focused to provide the most benefit. It is unlikely they would read a long report, so in order to provide better technical transfer of ideas and solutions, we recommend better coordination between CERL researchers and DPW staff responsible for specific energy, water, waste, infrastructure topics. The CERL team should work closely with DPW to explain recommendations and ensure DPW buy-in.

Personnel from multiple DPW divisions and branches have cross-functional roles in the budgeting, planning, design, engineering, operations and maintenance of facilities and infrastructure systems such as water: potable water treatment, metering, billing, and maintenance of the supply distribution system. CERL staff should schedule project meetings to gain an understanding of existing conditions and concerns and discuss ideas or recommendations with DPW staff who have shared responsibility for the technical area. CERL researchers can then follow-up to answer questions or provide additional information. Deliverables should be targeted to provide details needed to implement the proposed solution within the DPW business process.

DPW staff most likely to implement proposed solutions need to be invited to attend focused sessions during the quarterly ISSP IPRs. If they are unable to attend the ISSP IPRs, then CERL could offer IPRs at the DPW offices to get feedback on specific project ideas. Real project success occurs when the idea is implemented by the DPW process owner.

5.2.2 Update current practices to achieve high performance facilities

Current Army policy mandates high performance sustainable building principles, and those standards should be incorporated into DPW projects, Corps of Engineers projects, and TFW base maintenance contractor projects and repairs. Water fixtures and energy using devices/systems should be brought up to current standards when those items are replaced.

One example success story is the inclusion of standards requiring Water Sense fixtures when replacing broken or leaking plumbing fixtures by the TFW base contractor. CERL also helped several engineers in the DPW obtain updated ASHRAE and Army standards for use in building renovation projects. A systematic approach to assure all staff have current ASHRAE, federal and Army policies available to complete their daily tasks is recommended. Perhaps a webinar explaining how to obtain current standards using the Whole Building Design Guide would be useful to DPW staff. (See http://www.wbdg.org/)

CERL researchers also shared access to the U.S. Green Building Council training resources and emailed Fort Leonard Wood DPW staff details for many on-line educational webinars offered by USACE and other providers. These resources help DPW staff learn about current practices.

5.2.3 Metering recommendations

Appendix C contains information from the metering site visit to Fort Leonard Wood.

It is hard to track progress towards reduction in energy and water use if properly calibrated meters are not installed (and read) at individual buildings or facilities to measure gas, electricity, and water, plus chilled and hot water if appropriate. CERL has begun working with Fort Leonard Wood staff to understand the metering situation and determine how to obtain accurate metering data for specific buildings in order to calculate Energy Use Intensity (EUI). Much more work needs to be done to determine which buildings are metered, how the data is collected and stored, what the building occupancy schedules are, and how efficiently the buildings are using electricity, natural gas, water, steam and/or chilled water. Apparently many of the electric meters are associated with transformers, not individual buildings.

A more complicated effort would be to figure out how to connect Fort Leonard Wood meters to the Army's MDMS (Meter Data Management System) at Huntsville. There are many obstacles in this process, including meter standards and capabilities, funding for new meters, data transfer protocols and connections, and security requirements for wireless or wired internet connections.

Initially, 14 buildings were identified with water meters. Since reimbursable customers are billed for their usage, one recommendation is to install water meters at facilities that are high use or occupied by billable customers. Billing would be more accurate, and perhaps customers would conserve water to save money. Another suggestion is to determine if it is possible to install water meters to the potable water distribution system to determine water use on a larger scale. Finally, large water users such as the bulk distribution point, irrigated fields, or the large vehicle wash rack could be metered or better controlled to reduce water use.

Another opportunity is to make sure all the buildings occupied by reimbursable customers have working electric or natural gas meters.

5.2.4 Net Zero Energy recommendations

Chapter 2 explains how the energy baseline and base case were developed, and discusses ways to reduce energy in new construction, major renovations, and the use of co-generation or combined heat and power. Specific recommendations are discussed at the conclusion of Chapter 2.

During this project the Net Zero Planner was used to calculate a future base wide electrical load for the EITF (Energy Integration Task Force) team to use while considering feasibility of a large scale biomass project.

Also, the Net Zero Energy analysis showed that a combined heat and power (co-generation) facility for Specker Barracks would reduce site energy and be more efficient than replacing an old boiler with a similar one. It is proposed that next fiscal year the Energy team work with the Energy Manager and Master Planner at Fort Leonard Wood to develop an ECIP (Energy Conservation Investment Program) proposal to win funding for a Combined Heat and Power Co-Generation Project for Specker Barracks.

5.2.5 Net Zero Water recommendations

Chapter 3 recommends ways to characterize and reduce water use. Recommendations include better control and management of irrigation practices; and to change a location's use of potable water when there is no potable water use requirement. Future research topics include:

A regional water balance would provide insight into whether Fort Leonard Wood could be considered a Net Zero Water installation. Regional water modeling could estimate the amount of water that enters and leaves the Fort Leonard Wood watershed and help planners assess the risk to water supply.

Identification of water metrics and a more detailed characterization of how water is used would help Fort Leonard Wood track progress in water reduction.

It is also recommended that a detailed study looking at the actual cost of water be done. The real cost of water would be helpful in justifying water conservation projects and possibly improve billing to reimbursable customers.

Water technology retrofit guidelines could be written for use during design, construction, and operations and maintenance activities.

Finally, the "Buried No Longer" analysis tool could be tested to help Fort Leonard Wood plan investments for replacing and repairing the potable water infrastructure.

5.2.6 Net Zero Waste recommendations

Chapter 4 contains many recommendations to help Fort Leonard Wood reduce solid waste, increase recycling, and improve the deconstruction process when removing obsolete facilities.

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Appendix A: Net-Zero Planner Energy Analysis Process

Until very recently, defense installation planners addressed energy systems for new facilities on an individual facility basis without consideration of energy sources, renewables, storage, or future generation needs. Building retrofits under Sustainment, Restoration, and Modernization (SRM) projects typically do not address energy conservation. Energy Savings Performance Contract (ESPC) projects that address only easily achievable goals (improved efficiency of lighting, electrical, HVAC systems, controls, and Building Energy Management Systems [BEMSs]) will fail to maintain the current rate of energy reduction, and possibly fall short of meeting the rate required by the U.S. Energy Independence and Security Act of 2007 (EISA 2007), and will thereby become less economically attractive.

There is a lack of tools and case studies that address dynamics of energy systems at the community scale. Development and rapid deployment of such tools with dissemination of lessons learned through pilot energy master plans is essential in achieving the DoD mid- and long-term energy goals.

Most national and international research and policy energy-related efforts in the built environment focus on renewable energy sources and energy efficiency in single buildings. Organizations that have made first efforts to evaluate and analyze international experiences on planning and implementation of low energy communities include: the International Energy Agency (IEA) Energy Conservation in Buildings and Community Systems (ECBCS) Annex 51, the German funded project EnEff Stadt (a comprehensive approach to urban areas with local and district heating networks), the World Bank Energy Sector Management Assistance Program (ESMAP) Energy efficient cities initiative, and the Clinton Climate Initiative C40 program. The U.S. Army is pioneering a "Net Zero Installations" program for selected installations, which goes beyond zero energy and includes zero waste and zero water initiatives.

In community-wide energy planning, it is important to consider the integration of supply and demand, which leads to optimized solutions. The objective is to apply principles of a holistic approach to community energy planning and to provide the necessary methods and instruments to master planners, decision makers, and stakeholders. These comprehensive decision-making and modeling tools are not currently available.

The U.S. Army Engineer Research and Development Center (ERDC) has developed an energy optimization concept and automated tool called the Net Zero Planner to support DoD energy policy. The energy concept minimizes energy use at the building level, improves the efficiency of energy generation and distribution, and finally uses energy from renewable sources to balance fossil-generated energy to achieve a net zero fossil energy status. Energy goals will be achieved through synergy between energy use reduction in building-related systems and energy supply and distribution systems. The Net Zero Planner integrates optimization across buildings, distribution, and generation systems.

Objectives

The DoD has established challenging goals to increase energy efficiency and reduce the greenhouse gas (GHG) emissions of installations in all five services with an ultimate goal of Net Zero Energy (NZE) installations. These objectives are similar to those of some U.S. communities and college and university campuses. ERDC-CERL has developed a NZE installation concept and tool (Net Zero Planner) to support NZE planning for DoD installations.

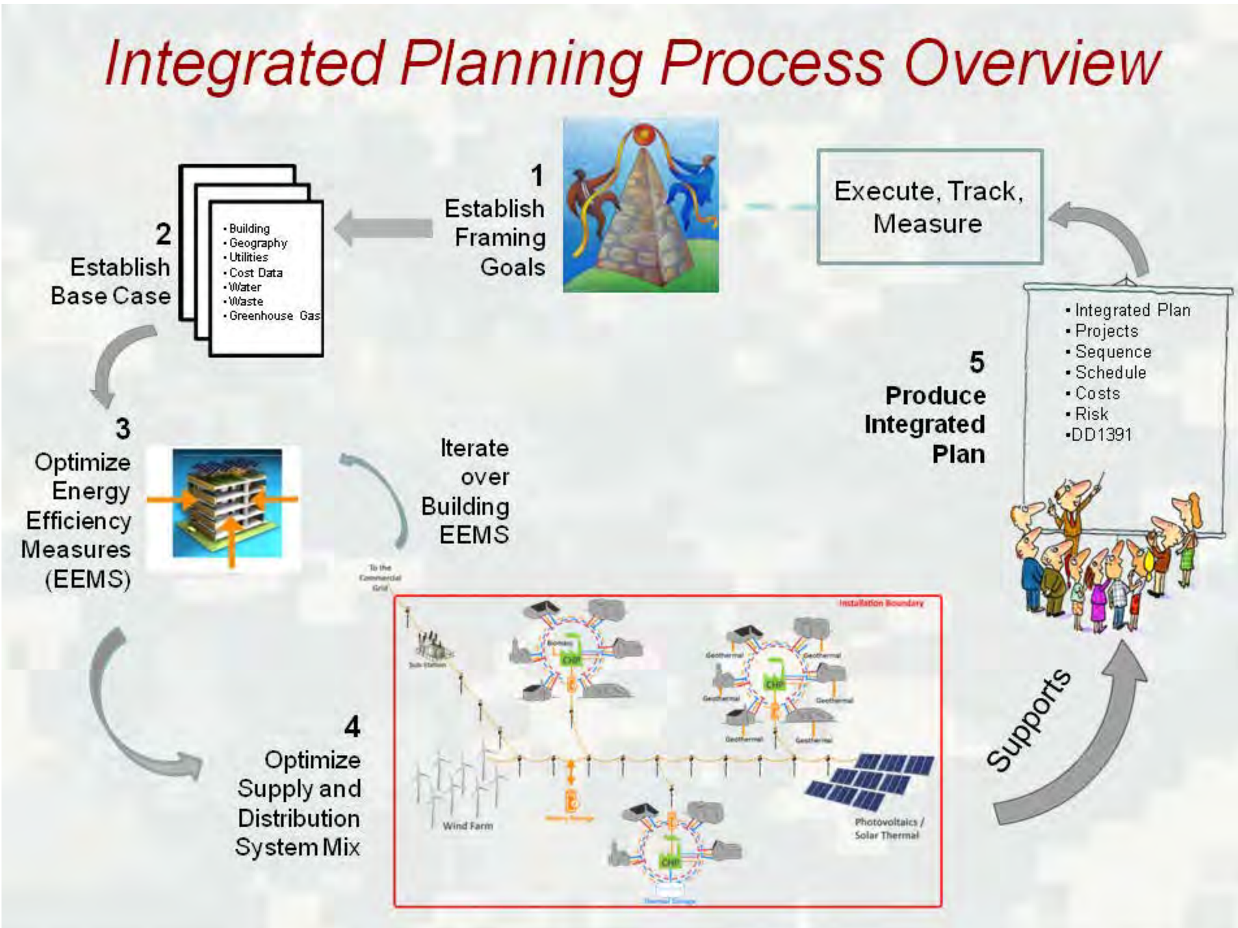
The Net Zero Planner will provide energy planners at installations the capability to create optimized plans to meet their energy goals (including net zero energy), by reducing overall energy use, using renewable energy sources, reducing GHG emissions, estimating costs, and evaluating risks. In addition to development of a roadmap for meeting site and source energy goals, the project is addressing other important DoD objectives, e.g., on-site uninterruptable energy generation to meet or exceed mission critical electrical and thermal needs; electrical peak reduction, use of solar thermal energy or waste heat from the cogeneration process, etc. This project will provide support for short, medium, and long-term investment and operational energy management decisions.

Net Zero Planner approach and modeling tool

The project team uses a collaborative and highly integrated planning process based on best practices from around the globe and best-in-class tools.

This process is shown in Figure A1. A variety of automated tools are typically used by most teams, including spreadsheets, stand-alone building energy simulations, and the Net Zero Planner being demonstrated by this project. This section will discuss the approach used by the team, including discussion of how the Net Zero Planner is used to support the process.

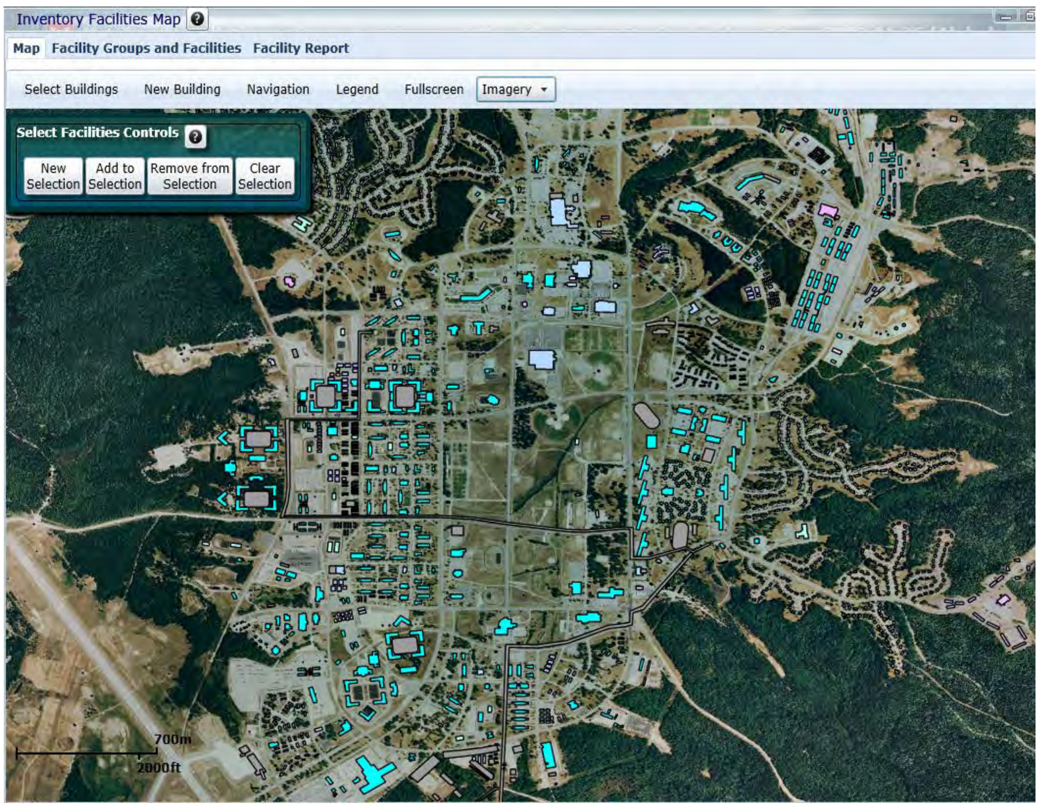
Figure A1. The Net Zero Planner process overview.



Step 1. Confirm scope and establish framing goals

The initial step in the process is to determine the scope of the installation's facilities and operations to be included in the study. This step begins with conversations with stakeholders and data from sources such as maps, Geospatial Information Systems (GIS), and spreadsheets obtained in a pre-visit. During the kickoff meeting, the team discusses which facilities, distribution networks, and energy conversion facilities to include. A geographical boundary (study area) is often established as well. Tenant facilities such as family housing, commissaries, and exchanges are generally included as an energy load to be met by the installation, but excluded for the purpose of recommended efficiency improvements if the installation does not have control of them. In the Net Zero Planner, the included facilities are selected by the Study Manager when the project is created (Figure A2). The buildings shown were imported into the tool from GIS data provided by the installation, which was modified as described below. Once established in the model, buildings can easily be added or removed. A list of these facilities is also kept in a master spreadsheet for reference by the team.

Figure A2. Using the Net Zero Planner to select buildings to be included in the scope of the Fort Leonard Wood net zero energy area.



Step 2. Select buildings to be included

Use the Net Zero Planner to select buildings to be included in the scope of the Fort Leonard Wood net zero energy area.

The team works with the installation stakeholders to develop energy goals early on, typically at the kick-off meeting. The goals serve to focus the study team and to engage in a serious discussion from the outset about what the installation would like to see accomplished. The goals should be challenging, but within the realm of possibility and informed by benchmarks such as EUI of best-in-class buildings around the world. Typical examples include increasing energy efficiency across the board or achieving zero fossil energy use. Energy goals are not a firm commitment, but rather a number to use when comparing alternative scenarios against a baseline. To be effective they should meet the following criteria:

- must encompass the entire study area,
- must balance often conflicting outcomes,
- may exceed existing targets in some aspects,
- the pathway to achieve them may not be clear at the start of the IEMP process,
- quantitative indicators should be easily derived from available data,
- non-quantitative goals should be core to final recommendations, and
- if achieved, would clearly be a success.

The goals are recorded in the Net Zero Planner and referred to frequently over the course of the study to remind the team what they are trying to achieve. The tool also has an optional Multi-Criteria Decision Analysis (MCDA) module that permits weights to be assigned to decision criteria that reflect their importance to the stakeholders. Once scenarios have been identified and the analysis has been done, the scenarios will be compared against the Energy goals. If the goals turn out not to have been feasible, then the team and installation stakeholders can engage in discussion about how to adjust them.

Step 3. Establishing a baseline

Before deciding on the path to reach a goal, it helps to know the starting point. The importance of establishing the *baseline* energy usage cannot be over emphasized. In this case, the baseline is defined as the current energy consumption profile and is a snapshot of an installation's *typical* annual energy profile. Climatic variation is normal from year to year, so mean values taken over a number of years should be used. Energy use should be broken down into categories relevant to the installation, such as the following:

1. End-uses
    - Building Functions
    - Industrial Processes
    - Central Services – Compressed Air / Water / Sewer
2. Distribution losses
    - Steam, hot water, cooling water, compressed air networks

- On-site electrical

3. On-site Conversion Losses
    - Gas Turbines
    - Reciprocating Engines
    - Boilers
    - Chillers
4. Off-site Conversion and Distribution Losses
    - Purchased natural gas
    - Purchased electricity

Site versus source energy

When discussing energy use, always be clear about whether you are discussing site energy or source energy. Site energy represents electrical, thermal, and chemical energy that is directly consumed* at the point of use (e.g., for heating, cooling, lights, or plug loads). Source energy refers to the primary fuel (coal, natural gas, diesel fuel, uranium, etc.) consumed in conversion from one type of energy to another secondary type of energy (i.e., coal to electricity) and in transmission of this energy to the site. Figure A3 illustrates how source energy is converted to electricity, transmitted to the site, and consumed as site energy at a building. Most experts estimate the average site/source efficiency of the U.S. commercial grid at about 30%. This means that if a building consumes electrical energy on site of about one million Btu/year, for instance, 3.33 million Btu/year of source energy at the power plant is required to produce it. Other primary fuels, such as natural gas, propane, and fuel oil incur losses in distribution as well and so have their own site-source conversion factors. The Environmental Protection Agency's (EPA) Energy Star program publishes source-site ratios for each of the primary and secondary fuels listed in its Portfolio Manager system [EPA, 2013†]. The EPA ENERGY STAR program uses national average conversion factors to avoid penalizing manufacturers for locally less efficient energy producers. Typical source-site ratios are listed in Table A1 below. For a given region, source-site ratios may be significantly different if there is a large amount of hydropower, solar power, or wind power in the mix, so it can be useful to also look at regional conversion ratios. The Net Zero Planner defaults to national average source-

* Of course, energy cannot be created or destroyed; it can only be changed from one form to another. We use the term consumed to signify using energy for some purpose.

† EPA, Energy Star: Portfolio Manager Technical Reference: Source Energy, http://www.energystar.gov/buildings/tools-and-resources/portfolio-manager-technical-reference-source-energy.

site ratios, but permits the users to substitute regional values. Regional values can be obtained from Deru, 2007. The Net Zero Planner always reports both site and source energy consumption to decision makers.

Figure A3. Source energy to site energy conversion is about 30% efficient.

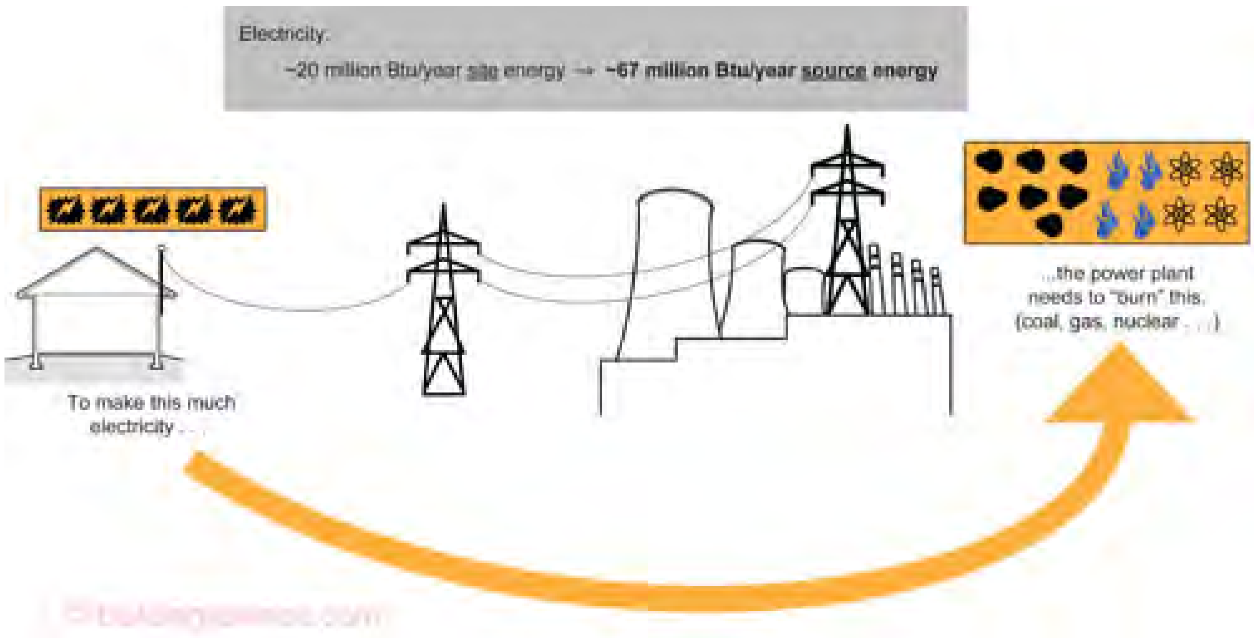


Table A1. National average source-site ratios for selected primary fuels.

Fuel Type	Source-Site Ratio
Electricity (Grid Purchase)	3.34
Natural Gas	1.047
Fuel Oil	1.01
Propane	1.01

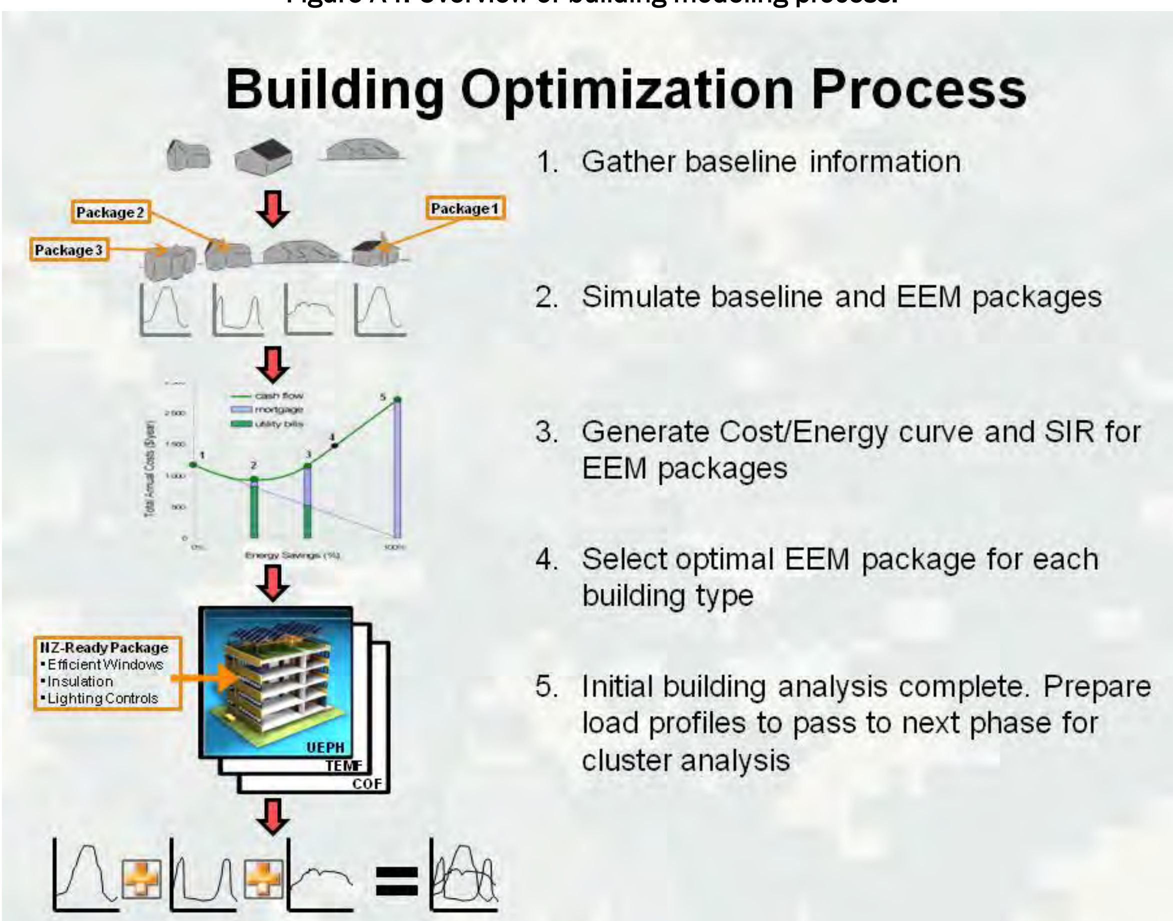
Estimating building energy loads and other end uses

In many cases, the lack of metered energy consumption data for buildings requires that a modeling process be used to estimate the makeup of an installation's energy use by the buildings. This process allows estimates of the community energy end-use to be meaningfully developed for complex, diverse sites with hundreds, or even thousands, of buildings, quickly and with an acceptable allocation of resources. Figure A4 shows the energy modeling process used by the team.

The first step of baseline building-level modeling characterizes the community as a whole in terms of the range of buildings it contains. Using all available information and observation from field visits, the total buildings inventory of the community is broken into main building categories (typically residential, non-residential and industrial).

Within each of these categories, the main types of buildings or building use are identified. Non-residential examples could be offices, retail, hospitality, etc. Residential examples could be barracks, single family homes, attached housing, multi-family homes, etc. Industrial examples include low-, medium- and high-energy processes.

Figure A4. Overview of building modeling process.



The Net Zero Planner tool has facilitated this process by providing a "library" of Army specific EnergyPlus-based energy models for each building use, type, and vintage that most closely matches the mix in the specific community. The models available in the Net Zero Planner were developed from common facility types built to U.S. Army Corps of Engineers Center

Of Standardization (COS) building standards. The models include: Army Reserve Center (ARC), Brigade Headquarters (BdeHQ) admin with moderate process loads, Battalion Headquarters (BnHQ) admin with low process loads, Child Development Center (CDC), Company Operations Facility (COF) admin with soldier readiness bays, Dining Facility (DFAC), General Instruction Building or School (GIB), General Purpose Warehouse (GPW), Information Systems Facility (InfoSys), Outpatient Healthcare Center (OHC), Tactical Equipment Maintenance Facility (TEMF), and Unaccompanied Enlisted Personnel Housing (UEPH) barracks.

In any community, there are some buildings that have mixed use; an example would be buildings that combine offices and warehousing, etc. To address these facility types there is a capability to specify a Custom Facility using defined space types. The “Custom” facility type automatically generates the geometry and zoning of the facility given a set of user inputs. All buildings are rectangular with a perimeter/core zone configuration with 15 ft deep perimeter zones and can be specified with the space types shown below:

Space type description
Active Storage
Assembly Area; Auditorium
Attic
Bulk Storage
Cafeteria
Classroom
Cold Storage
Commons
Conference Room
Corridor; Hallway
Data Center; Server Room
Dining Area
Fine Storage
Fitness
Kitchen
Laundry Room
Lockers
Mechanical Room
Office
Readi-Bay
Rectifier room
Residential; Barracks Room
Restroom

Space type description
Workshop
Stairwell
Storage
Telecommunications Room
Uninterruptable Power Supply Room
Utility Closet

These space types have set schedules and loads typical for that activity. The remaining structures typically have characteristics that cannot be reasonably generalized. For these "individual buildings" a specific energy model is assembled and the specific end-uses by building function are calculated. The Net Zero Planner has the capability to take energy simulation results from programs like eQuest or EnergyPlus simulated outside of the tool and then upload the resultant data into the Net Zero Planner for use as a facility type. The estimated utility use of each individual building is calculated using the appropriate individual models' Coefficients of Performance (COPs) and efficiencies for natural gas and electricity.

For this project the buildings were categorized into eight models, seven standard and one custom uploaded simulation results. Each of these representative models had their parameters modified to match the observed characteristics of the representative group of facilities and to match their vintage. Typical examples of modification could be the number of stories, insulation, windows specification, temperature setpoint, etc. It must be emphasized that any community specific modifications apply to the generalized model, not to any specific actual building. Each of the seven facility types were simulated by the energy parametric engine in the Net Zero Planner which is simply called "Params". The last facility type was for Religious and this was done as a custom upload to address the unique schedule of this facility type, but in hind sight was probably not necessary since the number of facilities of this type addressed in the study was under 50,000 SF or about 1% of the building area.

Each of these energy models was run in Params using EnergyPlus Version 7 to create energy end-use indexes in Btu/SF and kWh/m2 for the building functions of space heating and cooling, service hot water, fans, pumps, lighting and other electrically operated equipment. These building facility types were assigned to all of the buildings in the Fort Leonard Wood study area.

The generalized energy end-uses by building function is estimated by assigning the appropriate energy end-use indexes to each actual building based solely on their size (floor area). The estimated utility use of each actual building is calculated using the appropriate model's COPs or efficiencies for natural gas and electricity.

Calibration of building models

The total estimated utility needs of 38 building types and several vintages from the general and individual modeling process described above are combined for the study building inventory and compared to any available baseline metered gas, electricity or other utility data. If necessary, any significant discrepancies between metered and modeled data are resolved by adjusting the models using the team's experience and selected repeat site visits and data review. (Appendix B captures the master list of specific facilities that were modeled.)

After the previous calibration step the model results are reliable enough to identify the breakdown of energy use and cost by general building types, by groupings of actual buildings, and by specific functional end-uses. The model results are also the basis for prioritizing potential energy efficiency and energy productivity opportunities within similar groupings.

It is important to note that the modeling process described above is not a substitute for the detailed modeling of a single building. This detailed modeling would typically be done on selected buildings during subsequent implementation of the energy master planning recommendations for specific renovation projects to fine tune the strategic recommendations.

The Base Case

The *Base Case* includes the Baseline and factors in projected changes to the facility inventory or process loads to calculate projected energy consumption over the entire study period. Alternatives considering portfolios of EEMs, distribution, and supply measures may be compared against both the Baseline and Base Case.

The Baseline is a snapshot of the current energy performance at Fort Leonard Wood based on the average of fiscal years 2010 and 2011. The Base Case is a view of the future energy use, cost and emissions from taking a "business-as-usual" view of the future and assumes that the existing situation described in the Baseline will be changed only due to already planned projects of new construction, major renovation (OMA and SRM funded) and improvements conducted through the ESPC program. The Base Case acts as a reference for judging various alternative energy strategies. It also gives valuable perspectives into the potential energy-related risk that may need to be considered.

Scenario development

Energy master planning requires a comprehensive analysis of potential EEMs, with calculations carried through from final end-use through distribution, conversion, and finally to source fuel. Potentially, an unwieldy number of scenarios could be analyzed. A limited number of integrated scenarios are selected for detailed analysis in the next phase of developing the IEMP.

The process to select the alternative scenarios begins after the Baseline and Base Case are largely complete. These inform the team of the relative scale of each part of the energy value chain, its performance and potential risks and opportunities. Each alternative takes a distinctly different approach to potentially improving the overall energy efficiency and may have specific options that can be included or not included. Each alternative is analyzed and the results are assessed relative to the key energy goals (i.e. economic returns, efficiency, and supply security and emission reduction). The final recommendations are based on the alternative and options that most closely meet all energy goals.

The Net Zero Planner includes an optimization algorithm that automatically selects the best combination of energy conversion and storage devices to meet a particular set of building and industrial loads for each alternative. In addition to the Baseline and Base Case, a thermally distributed alternative is usually considered (i.e., boilers and chillers located in each building). In addition, existing district energy systems are analyzed for equipment changes, including conversion of steam to hot water. Other devices considered include cogeneration, thermal storage, electrical storage, and renewables such as solar photovoltaics and wind energy. The goal during scenario development is to set up alternatives that reflect broad constraints to be considered during the optimization phases that follow.

Facility-level optimization

Improving efficiency and reducing facility loads is almost always less expensive than making changes to distribution or supply systems. So measures such as insulation, lighting, low flow fixtures, etc, are considered before adding expensive renewable energy devices (e.g., photovoltaic [PV] solar panels) or other supply measures. Generically, any change done to a facility for the purpose of improving efficiency or reducing load is referred to as an EEM. Facility-level optimization refers to selecting the best set of EEMs for facilities on the installation to meet the installation's goals at the lowest cost.

The Net Zero Planner supports facility-level optimization by automatically applying packages of complimentary EEMs to the facility types specified during Baseline and Base Case development. The tool applies from six to twelve different packages to each facility type model, simulating the performances and cost of the EEM package using EnergyPlus on the Net Zero Planner server farm. The team then examines the output of the different EEM simulations and selects the most cost effective package for each facility type. Human judgment is important as well. The team assesses realistically available resources and makes a judgment regarding the number of EEMs that are reasonably likely to be implemented. For instance, the most cost effective time to add many EEMs to a building is during a major retrofit. Thus, the anticipated schedule of major retrofits plays a major role in the pace of EEM implementation.

Supply and distribution system optimization

Many installations began with centralized electrical and heating plants, usually using steam, and were then slowly converted to hot (and sometimes chilled) water distribution systems, or to completely decentralized systems using natural gas as a fuel and commercial power from the grid. Because of maintenance issues, steam distribution systems are almost never economically viable as new or recapitalized systems compared to modern hot water distribution systems, or even to completely decentralized systems. With a renewed emphasis on energy savings traced back to the source fuel, however, modern district systems may be the only way to meet policy goals economically. (Typical electrical generation, transmission, and distribution systems waste up to 70% of the source fuel compared to cogeneration electrical/heat/cooling plants.) The Net Zero Planner uses a module called NZI-Opt to perform calculations and optimization in this step to determine whether some form of centralized cogeneration or decentralization best meets the energy goals at the lowest cost. Industrial scale supply solutions such as solar photovoltaics, solar thermal, wind energy, biomass (wood chips, etc.), biogas, or synthetic gas are considered as part of the mix during distribution and supply optimization. They are almost always more expensive than making efficiency improvements or implementing cogeneration using natural gas fuel, but there may be other policy goals driving the use of these alternative technologies (e.g., Net Zero fossil fuel, support for a nascent industry, or energy security).

Plan and project formulation

The final integrated plan is produced by comparing the Baseline, Base Case, and alternatives using the criteria defined as part of the Energy Goals. MCDA methods may be used to support traceable decision processes and to integrate quantitative and qualitative factors selecting a preferred alternative. The NZP presents results as a decision table, with the Baseline, Base Case, and alternatives down one axis and decision criteria across the other axis so that all alternatives can be compared easily. Sensitivity analysis should be conducted using the alternatives and risk factors such as price volatility (what happens if natural gas prices double), availability (is there a domestic supply), and maintenance costs (e.g., relative risks of decentralized versus centralized equipment). The integrated plan contains a phased implementation strategy over the study period, showing investment costs (public or private), predicted energy, water, and waste reductions, and return on investment.

Appendix B: Facility List

Baseline facility list

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
ADMIN GEN PURP	401	Admin - existing - pre 1980 wood	BNHQ	1941	9567	2
CLASSROOM	975	Admin - existing - pre 1980 wood	BNHQ	1942	2500	1
CLASSROOM	978	Admin - existing - pre 1980 wood	BNHQ	1942	5310	1
OPERATION BR/WRK MGNT	2222	Admin - existing - pre 1980 wood	BNHQ	1942	7680	1
ADMIN GEN PUR	2204	Admin - existing - pre 1980 wood	BNHQ	1941	3525	1
ADMIN GEN PURP	2201	Admin - existing - pre 1980 wood	BNHQ	1941	2865	1
ADMIN GEN PURP	2202	Admin - existing - pre 1980 wood	BNHQ	1942	4005	1
ARMY RES CENTER	1350	ARC Existing - Post 1980	ARC	1987	18422	1
MAINT/STORAGE	1391	ARC Existing - Pre 1980	ARC	1967	2304	1
CTA at TA 183	1446	BdeHQ Existing - 90.1 2007	BdeHQ	2008	13264	1
3 CO FIRE STATION	580	BdeHQ Existing - Post 1980	BdeHQ	2000	17227	1
MP HQ/OPNS	1000	BdeHQ Existing - Post 1980	BdeHQ	1993	67434	1
DAVIDSON FITNESS CENTER	1300	BdeHQ Existing - Post 1980	BdeHQ	1994	75300	2
TELEVIDEO CENTER, HOGE	3200	BdeHQ Existing - Post 1980	BdeHQ	1989	139798	4
DISPATCH BLDG	5267	BdeHQ Existing - Post 1980	BdeHQ	1986	6012	1
COMPUTER CLASSROOM	708A	BdeHQ Existing - Post 1980	BdeHQ	2001	4325	1
CHAPLAIN ADMIN	590	BdeHQ Existing - Pre 1980	BdeHQ	1941	3263	2
BDE HQ BLDG	636	BdeHQ Existing - Pre 1980	BdeHQ	1964	9236	3
SHEA GYMNASIUM	640	BdeHQ Existing - Pre 1980	BdeHQ	1966	20425	1
BRIGADE HEADQUARTERS BLDG	741	BdeHQ Existing - Pre 1980	BdeHQ	1965	9236	3
SPECIAL PURPOSE CLASSROOM	746	BdeHQ Existing - Pre 1980	BdeHQ	1966	20425	1
BDE S-4	743	BdeHQ Existing - Pre 1980	BdeHQ	1966	3700	1
SWIFT GYM	826	BdeHQ Existing - Pre 1980	BdeHQ	1967	20425	1
BDE HEADQUARTERS	844	BdeHQ Existing - Pre 1980	BdeHQ	1967	9890	3
BDE HQ	1022	BdeHQ Existing - Pre 1980	BdeHQ	1971	6163	1
BDE HQ BLDG	1027	BdeHQ Existing - Pre 1980	BdeHQ	1971	11316	1
MUSEUM	1607	BdeHQ Existing - Pre 1980	BdeHQ	1970	75265	3
GYMNASIUM	1714	BdeHQ Existing - Pre 1980	BdeHQ	1979	16784	2
ENG ADMIN BLDG	2205_2008	BNHQ Demolish - Pre 1980	BNHQ	1959	2349	1
APPL INST BLDG	6020_2010	BNHQ Demolish - Pre 1980	BNHQ	1967	6390	1

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
BN HQ BLDG	650	BNHQ Demolish - Pre 1980	BNHQ	1965	6163	1
HOSTAGE NEGOTIATION BLDG	6050_2008	BNHQ Demolished - Post 1980	BNHQ	1988	3206	1
APPL INST BLDG	6130_2010	BNHQ Demolished - Post 1980	BNHQ	1988	1799	1
APPL INST BLDG	6131_2010	BNHQ Demolished - Post 1980	BNHQ	1988	1799	1
CLASSROOM, MARINES	6135_2010	BNHQ Demolished - Post 1980	BNHQ	1983	1158	1
INDOOR TRAINING	684	BNHQ Demolished - Post 1980	BNHQ	1988	25600	1
BN HQ BLDG	6100	BNHQ Existing - 90.1 2007	BNHQ	2010	23045	1
Community Center	N/A	BNHQ Existing - 90.1 2007	BNHQ	2013	7294	1
N/A	2134	BNHQ Existing - 90.1 2007	BNHQ	2013	13179	8
N/A	2132	BNHQ Existing - 90.1 2007	BNHQ	2013	4018	3
N/A	2133	BNHQ Existing - 90.1 2007	BNHQ	2013	2039	1
N/A	2131	BNHQ Existing - 90.1 2007	BNHQ	2013	3404	1
DPW ADMIN BLDG	2200B	BNHQ Existing - 90.1 2007	BNHQ	2010	5273	1
PRIME POWER SCHOOL	12630	BNHQ Existing - 90.1 2007	BNHQ	2010	48117	1
200 MAN CLASSROOM	894	BNHQ Existing - 90.1 2007	BNHQ	2008	6000	1
200 MAN CLASSROOM	912	BNHQ Existing - 90.1 2007	BNHQ	2009	6000	1
CBRN RESPONDER FACILITY	2130	BNHQ Existing - 90.1 2007	BNHQ	2007	39725	1
VISTOR CENTER, NORTH GATE	100	BNHQ Existing - Post 1980	BNHQ	2004	11742	1
GUARD BOOTH	101	BNHQ Existing - Post 1980	BNHQ	2005	607	1
SCHOOL/TRAINING CENTER	890	BNHQ Existing - Post 1980	BNHQ	1999	41676	2
GEN INST BLDG	2241	BNHQ Existing - Post 1980	BNHQ	2006	5048	1
APPL INST BLDG	12610	BNHQ Existing - Post 1980	BNHQ	1983	1800	1
CLASSROOM	5049A	BNHQ Existing - Post 1980	BNHQ	2006	2428	1
CLASSROOM	5049B	BNHQ Existing - Post 1980	BNHQ	2006	2428	1
GEN INST BLDG	5041	BNHQ Existing - Post 1980	BNHQ	2006	2501	1
SOLDIER SERVICE CENTER	470	BNHQ Existing - Post 1980	BNHQ	1995	101996	2
CID FACILITY	560	BNHQ Existing - Post 1980	BNHQ	1995	6281	1
INDOOR TRAINING	708	BNHQ Existing - Post 1980	BNHQ	1988	25600	1
750-MAN CLSRM	768	BNHQ Existing - Post 1980	BNHQ	1988	11500	1
DAVIS ENLISTED CLUB	805	BNHQ Existing - Post 1980	BNHQ	1984	17237	1
CLASSROOM	896	BNHQ Existing - Post 1980	BNHQ	2004	3690	1
CLASSROOM	964	BNHQ Existing - Post 1980	BNHQ	1999	9471	1
CLASSROOMS	961	BNHQ Existing - Post 1980	BNHQ	1999	37460	1
CLASSROOM	970	BNHQ Existing - Post 1980	BNHQ	1999	3441	1
CLASSROOMS	968	BNHQ Existing - Post 1980	BNHQ	1999	1452	1
CLASSROOMS	966	BNHQ Existing - Post 1980	BNHQ	1999	8007	1
CLASSROOM	963	BNHQ Existing - Post 1980	BNHQ	1999	9901	1
CLASSROOM	962	BNHQ Existing - Post 1980	BNHQ	1999	9394	1

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
BN HEADQUARTERS FOR 787MP	935	BNHQ Existing - Post 1980	BNHQ	2003	22917	1
CLASSROOM	971	BNHQ Existing - Post 1980	BNHQ	1999	23287	2
CLASSROOM	972	BNHQ Existing - Post 1980	BNHQ	1999	1000	1
CLASSROOM	974	BNHQ Existing - Post 1980	BNHQ	1999	1223	1
CLASSROOM	977	BNHQ Existing - Post 1980	BNHQ	1999	1742	2
CLASSROOM	976	BNHQ Existing - Post 1980	BNHQ	1999	1359	1
MTOC CLASSROOM	980	BNHQ Existing - Post 1980	BNHQ	1993	17630	1
CLASSROOM	973	BNHQ Existing - Post 1980	BNHQ	1999	1000	1
UNIT CHAPEL	1712	BNHQ Existing - Post 1980	BNHQ	1980	9050	1
RECEPTION FACILITY	2100	BNHQ Existing - Post 1980	BNHQ	1989	60844	1
ENGR ADM BLDG	2200	BNHQ Existing - Post 1980	BNHQ	2005	7238	1
ENTOMOLOGY FAC	2273	BNHQ Existing - Post 1980	BNHQ	1980	2800	1
MANSCEN NCOA HQ BLDG	3220	BNHQ Existing - Post 1980	BNHQ	1999	9106	1
CLASSROOM	3209	BNHQ Existing - Post 1980	BNHQ	2004	5940	1
GEN INST BLDG/LINCOLN	3201	BNHQ Existing - Post 1980	BNHQ	1989	146322	7
LIBRARY	3202	BNHQ Existing - Post 1980	BNHQ	1989	61000	7
GIF/THURMAN HALL	3203	BNHQ Existing - Post 1980	BNHQ	1999	288054	3
GEN INST BLDG	4191	BNHQ Existing - Post 1980	BNHQ	1982	2400	1
APPL INST BLDG	4190	BNHQ Existing - Post 1980	BNHQ	1980	2400	1
APPL INST BLDG	4194	BNHQ Existing - Post 1980	BNHQ	1986	1800	1
CLASSROOM	5046	BNHQ Existing - Post 1980	BNHQ	2001	2926	1
CLASSROOMS	5400	BNHQ Existing - Post 1980	BNHQ	1984	98932	3
CLSRM—TA 147	6022	BNHQ Existing - Post 1980	BNHQ	1986	1800	1
CLASSROOM	5080	BNHQ Existing - Post 1980	BNHQ	2005	3690	1
CLASSROOM	5081	BNHQ Existing - Post 1980	BNHQ	2005	3690	1
APPL INST BLDG	12710	BNHQ Existing - Post 1980	BNHQ	1983	1800	1
TRAINING BLDG	5101	BNHQ Existing - Post 1980	BNHQ	1999	49955	1
CLASSROOMS	5100	BNHQ Existing - Post 1980	BNHQ	1999	12321	1
GUARD HOUSE	5102	BNHQ Existing - Post 1980	BNHQ	1999	535	1
CLASSROOM	1394A	BNHQ Existing - Post 1980	BNHQ	2003	3240	1
APPL INST BLDG	5072	BNHQ Existing - Post 1980	BNHQ	1977	12400	1
ADMIN/CLSRM	5079	BNHQ Existing - Pre 1980	BNHQ	1976	1440	1
GEN INST BLDG	5077	BNHQ Existing - Pre 1980	BNHQ	1976	1440	1
ADMIN GEN PURP	315	BNHQ Existing - Pre 1980	BNHQ	1971	41707	4
ADMIN SPACE FOR MP-TASS	312	BNHQ Existing - Pre 1980	BNHQ	1965	23632	4
CLASSROOMS	320	BNHQ Existing - Pre 1980	BNHQ	1976	2617	1
DIAL CENTRAL OFC/ADMIN	404	BNHQ Existing - Pre 1980	BNHQ	1961	8516	1
POST CHAPEL	450	BNHQ Existing - Pre 1980	BNHQ	1962	12058	1
ARTS & CRAFTS CENTER	486	BNHQ Existing - Pre 1980	BNHQ	1977	14800	1
TRUMAN ED CTR	499	BNHQ Existing - Pre 1980	BNHQ	1975	39424	1
MAIN POST OFFICE	498	BNHQ Existing - Pre 1980	BNHQ	1964	30414	2
CARLSON TRAVEL	496	BNHQ Existing - Pre 1980	BNHQ	1968	1800	1

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
BN HQ BLDG	625	BNHQ Existing - Pre 1980	BNHQ	1965	6163	1
3 TNG BDE S-4	633	BNHQ Existing - Pre 1980	BNHQ	1963	12134	1
POST SAFETY OFFICE	631	BNHQ Existing - Pre 1980	BNHQ	1965	6163	1
UNIT CHAPEL	637	BNHQ Existing - Pre 1980	BNHQ	1964	8949	1
ADMIN GEN PURP	606	BNHQ Existing - Pre 1980	BNHQ	1965	11302	1
CLASSROOM	638	BNHQ Existing - Pre 1980	BNHQ	1965	3700	1
BAKER THEATER	607	BNHQ Existing - Pre 1980	BNHQ	1968	17086	3
BN HQ BLDG	658	BNHQ Existing - Pre 1980	BNHQ	1965	6163	1
BN HQS	732	BNHQ Existing - Pre 1980	BNHQ	1965	3795	1
CLASSROOM	749	BNHQ Existing - Pre 1980	BNHQ	1965	13280	1
UNIT CHAPEL	742	BNHQ Existing - Pre 1980	BNHQ	1966	8949	1
BN HQ BLDG	740	BNHQ Existing - Pre 1980	BNHQ	1965	6163	1
BN HQ BLDG	753	BNHQ Existing - Pre 1980	BNHQ	1965	6163	1
CLASSROOM	786	BNHQ Existing - Pre 1980	BNHQ	1960	9160	1
BN HQ BLDG	822	BNHQ Existing - Pre 1980	BNHQ	1966	6163	1
BN HQ BLDG	825	BNHQ Existing - Pre 1980	BNHQ	1966	6163	1
S4 ADMIN OFFICE	832	BNHQ Existing - Pre 1980	BNHQ	1967	3702	1
ABRAMS THEATRE	804	BNHQ Existing - Pre 1980	BNHQ	1972	17086	1
BAND TNG FAC	837	BNHQ Existing - Pre 1980	BNHQ	1967	13280	1
CLASSROOM	852	BNHQ Existing - Pre 1980	BNHQ	1966	2400	1
CLASSROOM	851	BNHQ Existing - Pre 1980	BNHQ	1966	2400	1
HQ - NAVY DET	838	BNHQ Existing - Pre 1980	BNHQ	1967	6163	1
ADMIN SPACE FOR MARINE	841	BNHQ Existing - Pre 1980	BNHQ	1967	12155	1
MARINES HQ	842	BNHQ Existing - Pre 1980	BNHQ	1967	6163	1
UNIT CHAPEL	843	BNHQ Existing - Pre 1980	BNHQ	1967	8890	2
ADMIN GEN PURP	1018	BNHQ Existing - Pre 1980	BNHQ	1971	3700	1
BN HQ BLDG	1009	BNHQ Existing - Pre 1980	BNHQ	1970	6163	1
CLASSROOM/ADMIN	1008	BNHQ Existing - Pre 1980	BNHQ	1970	6163	1
BN ADMIN & CLRM	1023	BNHQ Existing - Pre 1980	BNHQ	1971	6163	1
CLASSROOM	1134	BNHQ Existing - Pre 1980	BNHQ	1960	9160	1
GEN INST BLDG	1230	BNHQ Existing - Pre 1980	BNHQ	1960	9160	1
INSTRUCTION BLDG	1599	BNHQ Existing - Pre 1980	BNHQ	1966	2400	1
BOWLING CENTER	1609	BNHQ Existing - Pre 1980	BNHQ	1972	37354	1
ADMIN SPACE FOR MARINE	1702	BNHQ Existing - Pre 1980	BNHQ	1978	23411	1
ADMIN SPACE	1703	BNHQ Existing - Pre 1980	BNHQ	1978	19096	1
ADMIN GEN PURP	1705	BNHQ Existing - Pre 1980	BNHQ	1978	23411	1
BN HQ BLDG	1704	BNHQ Existing - Pre 1980	BNHQ	1978	9548	1
CLASSROOM FOR MARINES	1721	BNHQ Existing - Pre 1980	BNHQ	1978	2002	1
ADMIN AREA FOR MARINES	1772	BNHQ Existing - Pre 1980	BNHQ	1979	2002	1
CLASSROOM FOR MARINES	1760	BNHQ Existing - Pre 1980	BNHQ	1978	2002	1
ADMIN AREA FOR NAVY	1770	BNHQ Existing - Pre 1980	BNHQ	1978	2002	1
CALL FOR FIRE CLASSROOM	1750	BNHQ Existing - Pre 1980	BNHQ	1978	12929	1
DPW ADMIN BLDG	2224	BNHQ Existing - Pre 1980	BNHQ	1979	2024	1

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APPL INST BLDG	5059	BNHQ Existing - Pre 1980	BNHQ	1967	6600	1
APPL INST BLDG	5049	BNHQ Existing - Pre 1980	BNHQ	1970	3840	1
APPL INST BLDG	5048	BNHQ Existing - Pre 1980	BNHQ	1970	3840	1
APPL INST BLDG	5047	BNHQ Existing - Pre 1980	BNHQ	1970	3840	1
CLASSROOM	5042	BNHQ Existing - Pre 1980	BNHQ	1951	2872	1
GEN INST BLDG	5076	BNHQ Existing - Pre 1980	BNHQ	1977	1000	1
GEN INST BLDG	5075	BNHQ Existing - Pre 1980	BNHQ	1976	1440	1
DIRECTOR'S OFFICE	2200A	BNHQ Existing - Pre 1980	BNHQ	1966	3504	1
ENL BK W/O DIN	318	BNHQ Existing - Pre 1980	BNHQ	1976	12174	3
ENL BK W/O DIN	319	BNHQ Existing - Pre 1980	BNHQ	1976	12174	3
ADMIN GEN PURPOSE	2226	BNHQ Existing - Pre 1980	BNHQ	1977	3504	1
BN HQ BLDG	750	BNHQ Existing - Pre 1980	BNHQ	1965	6106	1
INDOOR CLASSROOM	1445	BNHQ Existing - Pre 1980	BNHQ	1961	9855	1
CLASSROOMS FOR AIR FORCE	1006	BNHQ Existing - Pre 1980	BNHQ	1970	12132	1
ADMIN	1706	BNHQ Existing - Pre 1980	BNHQ	1978	23437	1
GAME WARDEN & ANIMAL CONT	1614	BNHQ Existing - Pre 1980	BNHQ	1961	2596	1
VET FACILITY	2399	BNHQ Existing - Pre 1980	BNHQ	1964	6011	1
CDC SCHOOL AGE	616	CDC Existing - 90.1 2007	CDC	2009	23576	1
CHILD DEVELOPMENT CENTER	615	CDC Existing - Post 1980	CDC	1995	24500	1
ADM & SUP BLDG	655	COF Demolish - Pre 1980	COF	1961	12134	1
ADM & SUP BLDG	656	COF Demolish - Pre 1980	COF	1961	12134	1
ARNG ARMORY	986	COF Existing - Post 1980	COF	1997	30192	1
HQS PART OF BLDG	2107	COF Existing - Post 1980	COF	2001	26900	3
HQS PART OF BLDG	2109	COF Existing - Post 1980	COF	2001	49763	3
HQS PART OF BLDG	2108	COF Existing - Post 1980	COF	2001	49763	3
CO HQ BLDG	2113	COF Existing - Post 1980	COF	2005	2741	1
ADM & SUP BLDG	626	COF Existing - Pre 1980	COF	1964	12155	1
COMPANY HEADQUARTERS	734	COF Existing - Pre 1980	COF	1965	12155	1
CO HQ BLDG	733	COF Existing - Pre 1980	COF	1965	12155	1
CO HQ BLDG	751	COF Existing - Pre 1980	COF	1966	12155	1
ADM & SUP BLDG (A, B & D)	752	COF Existing - Pre 1980	COF	1966	12156	1
ADM & SUP BLDG	823	COF Existing - Pre 1980	COF	1966	12155	1
CO HQ BLDG	824	COF Existing - Pre 1980	COF	1966	12155	1
STORAGE	840	COF Existing - Pre 1980	COF	1967	7152	1
ADM & SUP BLDG	1007	COF Existing - Pre 1980	COF	1970	12155	1
ADM & SUP BLDG	1025	COF Existing - Pre 1980	COF	1971	12155	1
ADM & SUP BLDG	1701	COF Existing - Pre 1980	COF	1978	23411	1
CO HQ BLDG	1707	COF Existing - Pre 1980	COF	1979	14047	1
ENL PERS DINE	657	DFAC Demolish - Pre 1980	DFAC	1961	13280	1
ENL PERS DINE	653	DFAC Demolish - Pre 1980	DFAC	1961	13280	1
DBL DINNING FACILITY	6111	DFAC Existing - 90.1 2007	DFAC	2011	62234	1
DINING FACILITY	930	DFAC Existing - Post 1980	DFAC	2004	34789	1

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GRANT HALL DINING	2105	DFAC Existing - Post 1980	DFAC	1990	16856	1
UPEH DINING FACILITY	3223	DFAC Existing - Post 1980	DFAC	1999	20580	1
ENL PERS DINE	630	DFAC Existing - Pre 1980	DFAC	1964	13280	1
ENL PERS DINE	735	DFAC Existing - Pre 1980	DFAC	1965	13280	1
ENL PERS DINE	739	DFAC Existing - Pre 1980	DFAC	1965	13280	1
ENL PERS DINE	754	DFAC Existing - Pre 1980	DFAC	1966	13280	1
ENL PERS DINE	821	DFAC Existing - Pre 1980	DFAC	1966	13280	1
ENL PERS DINE	820	DFAC Existing - Pre 1980	DFAC	1966	13280	1
ENL PERS DINE, EDP	836	DFAC Existing - Pre 1980	DFAC	1967	13280	1
ENL PERS DINE, EDP	1010	DFAC Existing - Pre 1980	DFAC	1971	11316	1
ENL PERS DINE, EDP	1011	DFAC Existing - Pre 1980	DFAC	1970	11316	1
ENL PERS DINE, EDP	1740	DFAC Existing - Pre 1980	DFAC	1979	22919	1
ENL PERS DINE	5073	DFAC Existing - Pre 1980	DFAC	1952	9600	1
Large Chapel Complex	N/A	Religious Existing - 90.1 2007	Religious	2013	27463	1
GEN PURPOSE WHSE	2563	TEMF Demolish - Pre 1980	TEMF	1942	18561	1
MOTOR POOL BLDG	673	TEMF Demolish - Pre 1980	TEMF	1964	4786	1
VEH MAINT SHOP	5262	TEMF Existing - Post 1980	TEMF	2006	8522	1
STORAGE	5263	TEMF Existing - Post 1980	TEMF	2002	5549	1
FORKLIFT TNG CLASSROOM	663	TEMF Existing - Post 1980	TEMF	1982	12834	2
MAINTENANCE FACILITY	897	TEMF Existing - Post 1980	TEMF	2005	3600	1
CATF WAREHOUSE	895	TEMF Existing - Post 1980	TEMF	1999	13900	1
VEHICLE MNT SH ORG-MTOC	950	TEMF Existing - Post 1980	TEMF	1994	26834	2
READY BLDG/WWD BLDG	1270	TEMF Existing - Post 1980	TEMF	2003	12300	1
GEN INST BLDG-KIMBRO HALL	12700	TEMF Existing - Post 1980	TEMF	1987	23880	1
ROBOTIC TECH/MAINT	1590	TEMF Existing - Post 1980	TEMF	1994	2250	1
43D AGBN S-4	2110	TEMF Existing - Post 1980	TEMF	2001	4412	1
RAILROAD AMINT BLDG	2231	TEMF Existing - Post 1980	TEMF	2003	1560	1
MAINT SHOP-TRAIN	2230	TEMF Existing - Post 1980	TEMF	1994	3600	1
SUPPLY STORE	2346	TEMF Existing - Post 1980	TEMF	1941	10500	1
STORAGE	2550	TEMF Existing - Post 1980	TEMF	2003	5200	1
BATTERY SHOP	5265	TEMF Existing - Post 1980	TEMF	1985	199353	1
STORAGE MP EQUIPMENT	5264	TEMF Existing - Post 1980	TEMF	2000	3600	1
RANGE SUPPORT BLDG	12740	TEMF Existing - Post 1980	TEMF	1998	320	1
VEH MNT SH ORG	5069	TEMF Existing - Post 1980	TEMF	1980	13000	1
APPL INST BLDG-KAWAMURA	5074	TEMF Existing - Post 1980	TEMF	1981	32044	1
SUPPORT BUILDING	12705	TEMF Existing - Post 1980	TEMF	2002	4368	1
K-SPAN	5079A	TEMF Existing - Post 1980	TEMF	2003	4992	1
VEH PAINT/AUTO BODY SHOP	5266	TEMF Existing - Post 1980	TEMF	1986	7560	1
APPL INST BLDG	5051	TEMF Existing - Pre-1980	TEMF	1966	7680	1
FE STOREHOUSE	599	TEMF Existing - Pre-1980	TEMF	1941	18270	1
STORAGE	632	TEMF Existing - Pre-1980	TEMF	1963	13280	1
VEH MNT SH ORG	672	TEMF Existing - Pre-1980	TEMF	1964	4786	1
VEH MNT SHOP	680	TEMF Existing - Pre-1980	TEMF	1964	4786	1

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VEH MNT SH ORG	681	TEMF Existing - Pre-1980	TEMF	1964	4786	1
VEH MNT SH ORG	773	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	772	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	780	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	781	TEMF Existing - Pre-1980	TEMF	1966	4786	1
STORAGE SPACE	8208	TEMF Existing - Pre-1980	TEMF	1971	3648	1
VEH MNT SH ORG	872	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	873	TEMF Existing - Pre-1980	TEMF	1966	4786	1
MAINT BUILDING	880	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	881	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	991	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	998	TEMF Existing - Pre-1980	TEMF	1966	4786	1
LAWNMOWER REPAIR SHOP	1549	TEMF Existing - Pre-1980	TEMF	1960	9479	1
VEH MNT SH ORG	999	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	990	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	1390	TEMF Existing - Pre-1980	TEMF	1977	10550	1
AUTO CRAFTS SHOP	1383	TEMF Existing - Pre-1980	TEMF	1973	8840	1
MAINTENANCE/ADMIN	1588	TEMF Existing - Pre-1980	TEMF	1941	3108	1
VEH MAINT SHOP	2250	TEMF Existing - Pre-1980	TEMF	1977	1862	1
ADM & SUP BLDG	2314	TEMF Existing - Pre-1980	TEMF	1941	9267	2
STORAGE, EDP OFFICE	2318	TEMF Existing - Pre-1980	TEMF	1941	9267	1
TRAINING	2385	TEMF Existing - Pre-1980	TEMF	1941	3203	1
STORAGE	4199	TEMF Existing - Pre-1980	TEMF	1963	2400	1
CAR RENTAL	2555	TEMF Existing - Pre-1980	TEMF	1941	3108	1
APPL INST BLDG	5056	TEMF Existing - Pre-1980	TEMF	1967	1836	1
APPL INST BLDG	5052	TEMF Existing - Pre-1980	TEMF	1966	14480	2
VEH MNT SH ORG	5053	TEMF Existing - Pre-1980	TEMF	1966	29225	1
APPL INST BLDG	5050	TEMF Existing - Pre-1980	TEMF	1966	7436	1
VEH MNT SH ORG	5071	TEMF Existing - Pre-1980	TEMF	1952	9594	1
APPL INST	5070	TEMF Existing - Pre-1980	TEMF	1976	14400	1
TERMINAL EQUIPMENT BLDG	435	TEMF Existing - Pre-1980	TEMF	1959	1757	1
COMB AC HT BLDG	745	TEMF Existing - Pre-1980	TEMF	1965	4665	1
N/A	745A	TEMF Existing - Pre-1980	TEMF	2013	2156	1
COMB AC HT BLDG	1021	TEMF Existing - Pre-1980	TEMF	1971	6163	1
WATER TRMT BLDG	1601	TEMF Existing - Pre-1980	TEMF	1941	7664	1
HEAT PLANT BLDG	2369	TEMF Existing - Pre-1980	TEMF	1978	13757	2
CATF WAREHOUSE	898	TEMF Existing 90.1 2007	TEMF	2010	14547	1
DOL CENTRAL RECEIVING	2562A	TEMF Existing 90.1 2007	TEMF	2010	4953	1
TEMPORARILY 4TH MEB	2333	TEMF Existing 90.1 2007	TEMF	2009	4783	1
DOL CENTRAL RECEIVING WAREHSE	2562	TEMF Existing 90.1 2007	TEMF	2009	4783	1
RG SPT FAC	12742	TEMF Existing 90.1 2007	TEMF	2010	6800	1
RG SPT FAC	12741	TEMF Existing 90.1 2007	TEMF	2010	6800	1

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Lawn Mtce Bldg	6106	TEMF Existing 90.1 2007	TEMF	2010	2652	1
ENL BKS BASIC TRAINING	654	Trainee Barracks - Demolish - Pre 1980	Training Barracks	1961	54484	3
ENL BKS BASIC TRAINING	660	Trainee Barracks - Demolish - Pre 1980	Training Barracks	1961	40990	3
ENL BKS BASIC TRAINING	659	Trainee Barracks - Demolish - Pre 1980	Training Barracks	1961	40990	3
ENL BKS BASIC TRAINING	652	Trainee Barracks - Demolish - Pre 1980	Training Barracks	1961	40990	3
ENL BKS BASIC TRAINING	651	Trainee Barracks - Demolish - Pre 1980	Training Barracks	1961	40990	3
TRAINEE BARRACKS	2113D	Trainee Barracks Existing - Post 1980	Training Barracks	2005	2912	1
TRAINEE BARRACKS	2113F	Trainee Barracks Existing - Post 1980	Training Barracks	2005	2912	1
TRAINEE BARRACKS	2113E	Trainee Barracks Existing - Post 1980	Training Barracks	2005	2912	1
TRAINEE BARRACKS	2113C	Trainee Barracks Existing - Post 1980	Training Barracks	2005	2912	1
TRAINEE BARRACKS	2113A	Trainee Barracks Existing - Post 1980	Training Barracks	2005	2912	1
N/A	2113B	Trainee Barracks Existing - Post 1980	Training Barracks	2005	2912	1
AIT B/COF	N/A	Training Barracks - Existing - 90.1 2007	Training Barracks	2013	106000	3
AIT B/COF	N/A	Training Barracks - Existing - 90.1 2007	Training Barracks	2013	106000	3
AIT B/COF	N/A	Training Barracks - Existing - 90.1 2007	Training Barracks	2013	106000	3
TRAINEE BARRACKS	932	Training Barracks - Existing - 90.1 2007	Training Barracks	2004	55660	3
TRAINEE BARRACKS	934	Training Barracks - Existing - 90.1 2007	Training Barracks	2004	55660	3
BARRACKS	936	Training Barracks - Existing - 90.1 2007	Training Barracks	2004	55660	3
BARRACKS	937	Training Barracks - Existing - 90.1 2007	Training Barracks	2004	55660	3
TRAINEE BARRACKS	939	Training Barracks - Existing - 90.1 2007	Training Barracks	2004	55660	3
B/COF	N/A	Training Barracks - Existing - 90.1 2007	Training Barracks	2013	55660	3
B/COF	N/A	Training Barracks - Existing - 90.1 2007	Training Barracks	2013	55600	3
BCOF - Trainee Barracks	6103	Training Barracks - Existing - 90.1 2007	Training Barracks	2010	55600	3
BCOF - Trainee Barracks	6104	Training Barracks - Existing - 90.1 2007	Training Barracks	2010	55600	3
BCOF - Trainee Barracks	6102	Training Barracks - Existing - 90.1 2007	Training Barracks	2010	55600	3

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
BCOF - Trainee Barracks	6101	Training Barracks - Existing - 90.1 2007	Training Barracks	2010	55600	3
ENL BKS BASIC TRAINING	628	Training Barracks Existing - Pre 1980	Training Barracks	1964	40640	3
ENL BKS BASIC TRAINING	627	Training Barracks Existing - Pre 1980	Training Barracks	1964	40640	3
ENL BKS BASIC TRAINING	629	Training Barracks Existing - Pre 1980	Training Barracks	1964	40640	3
ENL BKS BASIC TRAINING	635	Training Barracks Existing - Pre 1980	Training Barracks	1963	40990	3
TRAINEE BKS	634	Training Barracks Existing - Pre 1980	Training Barracks	1963	40990	3
ENL BKS OSUT	757	Training Barracks Existing - Pre 1980	Training Barracks	1966	40640	3
ENL BKS OSUT	737	Training Barracks Existing - Pre 1980	Training Barracks	1965	40640	3
ENL BKS AIT	756	Training Barracks Existing - Pre 1980	Training Barracks	1966	40640	3
ENL BKS AIT	755	Training Barracks Existing - Pre 1980	Training Barracks	1966	40640	3
ENL BKS OSUT	747	Training Barracks Existing - Pre 1980	Training Barracks	1965	40640	3
ENL BKS OSUT	748	Training Barracks Existing - Pre 1980	Training Barracks	1965	40640	3
ENL BKS OSUT	738	Training Barracks Existing - Pre 1980	Training Barracks	1965	40640	3
ENL BKS BASIC TRAINING	736	Training Barracks Existing - Pre 1980	Training Barracks	1965	40640	3
ENL BKS BASIC TRAINING	730	Training Barracks Existing - Pre 1980	Training Barracks	1965	40640	3
ENL BKS BASIC TRAINING	731	Training Barracks Existing - Pre 1980	Training Barracks	1965	40640	3
BATH HOUSE	604	Training Barracks Existing - Pre 1980	Training Barracks	1961	4918	1
ENL BKS OSUT	1014	Training Barracks Existing - Pre 1980	Training Barracks	1970	40639	3
ENL BKS OSUT	1016	Training Barracks Existing - Pre 1980	Training Barracks	1971	40639	3
ENL BKS OSUT	1013	Training Barracks Existing - Pre 1980	Training Barracks	1970	40639	3
ENL BKS OSUT	1015	Training Barracks Existing - Pre 1980	Training Barracks	1971	40639	3
ENL BKS OSUT	1012	Training Barracks Existing - Pre 1980	Training Barracks	1970	40639	3
ENL BKS OSUT	1029	Training Barracks Existing - Pre 1980	Training Barracks	1971	40639	3
ENL BKS OSUT	1028	Training Barracks Existing - Pre 1980	Training Barracks	1971	40640	3
ITRO STUDENTS, AIR FORCE	1729	Training Barracks Existing - Pre 1980	Training Barracks	1978	24664	3

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
PERM PARTY BKS, 1 ENG BDE	1731	Training Barracks Existing - Pre 1980	Training Barracks	1979	11343	3
BARRACKS	1720	Training Barracks Existing - Pre 1980	Training Barracks	1978	24644	3
RESERVE COMP BARRACKS	1724	Training Barracks Existing - Pre 1980	Training Barracks	1978	11232	3
ITRO TRAINEE BKS, AIR FOR	1728	Training Barracks Existing - Pre 1980	Training Barracks	1979	24664	3
BARRACKS, MED HOLD	1723	Training Barracks Existing - Pre 1980	Training Barracks	1978	24644	3
ENLISTED UPH	1732	Training Barracks Existing - Pre 1980	Training Barracks	1979	11343	3
ENL PERM PARTY, 577 ENG	1735	Training Barracks Existing - Pre 1980	Training Barracks	1979	24664	3
PERM PARTY, ITRO	1733	Training Barracks Existing - Pre 1980	Training Barracks	1979	11343	3
ENL PERM PARTY	1734	Training Barracks Existing - Pre 1980	Training Barracks	1979	24664	3
MARINE ITRO BARRACKS	1726	Training Barracks Existing - Pre 1980	Training Barracks	1979	11343	3
PERM PARTY BARRACKS	1730	Training Barracks Existing - Pre 1980	Training Barracks	1978	11343	3
ITRO TRAINEE BKS, AIR FOR	1725	Training Barracks Existing - Pre 1980	Training Barracks	1978	11343	3
RESERVE COMP BARRACKS	1722	Training Barracks Existing - Pre 1980	Training Barracks	1978	11343	3
ITRO TRAINEE BKS, MARINES	1765	Training Barracks Existing - Pre 1980	Training Barracks	1978	24664	3
ITRO TRAINEE BKS, MARINES	1764	Training Barracks Existing - Pre 1980	Training Barracks	1978	11343	3
ITRO TRAINEE BKS, MARINES	1775	Training Barracks Existing - Pre 1980	Training Barracks	1979	11343	3
ITRO TRAINEE BKS, MARINE	1774	Training Barracks Existing - Pre 1980	Training Barracks	1979	11343	3
ITRO TRAINEE BKS, MARINES	1763	Training Barracks Existing - Pre 1980	Training Barracks	1978	11343	3
MARINE ITRO BARRACKS	1773	Training Barracks Existing - Pre 1980	Training Barracks	1979	24664	3
ITRO TRAINEE BKS, MARINES	1767	Training Barracks Existing - Pre 1980	Training Barracks	1978	24664	3
ITRO TRAINEE BKS, MARINES	1761	Training Barracks Existing - Pre 1980	Training Barracks	1978	24664	3
ITRO TRAINEE BKS, MARINE	1771	Training Barracks Existing - Pre 1980	Training Barracks	1979	11343	3
ITRO TRAINEE BKS, MARINE	1769	Training Barracks Existing - Pre 1980	Training Barracks	1978	24664	3
ITRO TRAINEE BKS, MARINES	1762	Training Barracks Existing - Pre 1980	Training Barracks	1978	11343	3
ITRO TRAINEE BKS, NAVY	1766	Training Barracks Existing - Pre 1980	Training Barracks	1978	11343	3

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
ITRO TRAINEE BKS, NAVY	1768	Training Barracks Existing - Pre 1980	Training Barracks	1978	11343	3
ITRO TRAINEE BKS, MARINES	1776	Training Barracks Existing - Pre 1980	Training Barracks	1979	24664	3
DET DAY ROOM	1736	Training Barracks Existing - Pre 1980	Training Barracks	1978	2002	1
DET DAY ROOM	1727	Training Barracks Existing - Pre 1980	Training Barracks	1978	2002	1
DET LATRINE/SHOWER BLDG	688	Training Barracks Existing - Pre 1980	Training Barracks	1966	2354	1
ENL BKS OSUT	817	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1966	40640	3
ENL BKS OSUT	818	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1966	40640	3
ENL BKS OSUT	819	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1966	40640	3
ENL BKS OSUT	816	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1966	40640	3
ENL BKS OSUT	815	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1966	40640	3
ENL BKS OSUT	831	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1967	40640	3
ENL BKS OSUT	830	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1967	40640	3
ENL BKS OSUT	829	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1967	40640	3
ENL BKS OSUT	828	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1967	40640	3
ENL BKS AIT	827	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1967	40640	3
FE MAINT SHOP	2212	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1942	8352	1
LUM & P SHED FE	2214	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1943	5184	1
LUM & P SHED FE	2213	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1943	4998	1
ADMIN GEN PURP/STORAGE	2208	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1942	8352	1
CARPENTER SHOP/LOCKSMITH	2216	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1942	4608	2
CARPENTER SHOP	2215	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1942	6144	1
WORK CONTROL SECTION	2203	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1941	2434	1
SIGN SHOP	2217	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1942	3200	1
FE MAINT SHOP	2207	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1942	3200	1
FE MAINT SHOP (PLUMBING)	2227	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1970	640	1

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
DET LATRINE/SHOWER BLDG	853	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1966	2400	1
Enlisted UPH	1954	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1952	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1953	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1955	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1957	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1931	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1950	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1951	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1926	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1925	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1922	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1923	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1921	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1924	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1920	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1959	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1956	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1918	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1916	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1919	UEPH Existing	UEPH	2008	2536	1
Enlisted UPH	1913	UEPH Existing	UEPH	2008	2537	1
Enlisted UPH	1914	UEPH Existing	UEPH	2008	2536	1
Enlisted UPH	1917	UEPH Existing	UEPH	2008	2536	1
Enlisted UPH	1915	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1911	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1909	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1907	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1904	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1912	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1910	UEPH Existing	UEPH	2008	2540	1
Enlisted UPH	1908	UEPH Existing	UEPH	2008	2536	1
Enlisted UPH	1902	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1900	UEPH Existing	UEPH	2008	2534	1
Enlisted UPH	1901	UEPH Existing	UEPH	2008	2533	1
Enlisted UPH	1906	UEPH Existing	UEPH	2008	2536	1
Enlisted UPH	1960	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1940	UEPH Existing	UEPH	2009	2534	1
Enlisted UPH	1942	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1944	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1946	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1948	UEPH Existing	UEPH	2009	2535	1

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
Enlisted UPH	1947	UEPH Existing	UEPH	2009	2534	1
Enlisted UPH	1945	UEPH Existing	UEPH	2009	2534	1
Enlisted UPH	1943	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1941	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1961	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1964	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1965	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1966	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1968	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1969	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1967	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1962	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1938	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1936	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1939	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1937	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1934	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1932	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1930	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1935	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1933	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1963	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1958	UEPH Existing	UEPH	2009	2535	1
LUM & P SHED FE	3301	Warehouse Existing - post 1980 Metal Building	GPW	1983	2556	1
LUM & P SHED FE	3302	Warehouse Existing - post 1980 Metal Building	GPW	1983	2861	1
LUM & P SHED FE	3300	Warehouse Existing - post 1980 Metal Building	GPW	1982	2592	1
FE STORAGE	2313	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
CLOTHING ISSUE	2324	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
GENERAL PURPSE WHSE	2334	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
GEN PURPOSE WHSE	2345	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
GEN PURPOSE WHSE	2344	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
BIN WHSE	2337	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
FE STOREHOUSE	2315	Warehouse - Existing - Pre 1980	GPW	1942	9000	1
STORAGE	2342	Warehouse - Existing - Pre 1980	GPW	1941	9267	2

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
GENERAL PURPSE WHSE	2335	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
WHSE	2341	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
BIN WHSE	2336	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
STORAGE, U-STORE-IT	2343	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
CLOTHING WHSE	2323	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
CLOTHING ISSUE	2322	Warehouse - Existing - Pre 1980	GPW	1941	11246	1
CLOTHING WHSE	2321	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
CLOTHING ISSUE/WHSE	2339	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
CLOTHING ISSUE/WHSE	2338	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
FE STORAGE	2319	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
CLOTHING ISSUE	2320	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
WHSE	2340	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
STORAGE	2303	Warehouse - Existing - Pre 1980	GPW	1941	1625	1
STORAGE	2330	Warehouse - Existing - Pre 1980	GPW	1941	9324	1
EXCH WAREHOUSE	2331	Warehouse - Existing - Pre 1980	GPW	1941	9266	2
GEN PURPOSE WHSE	2310	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
GEN STOREHOUSE	2325	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
GEN PURPOSE WHSE	2311	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
GEN PURPOSE WHSE	2326	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
EXCHANGE WAREHOUSE	2332	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
ENVIRON STORAGE	2307	Warehouse - Existing - Pre 1980	GPW	1941	1625	1
STORAGE	2306	Warehouse - Existing - Pre 1980	GPW	1941	1625	1
STORAGE	2305	Warehouse - Existing - Pre 1980	GPW	1941	1625	1
HAZMAT STOR/WEAPONS STOR	2308	Warehouse - Existing - Pre 1980	GPW	1941	15275	2
STORAGE AREA FOR 577	2304	Warehouse - Existing - Pre 1980	GPW	1941	1955	1

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
MAINT/STORAGE	2558	Warehouse - Existing - Pre 1980	GPW	1941	3108	1
MAINT/STORAGE	2557	Warehouse - Existing - Pre 1980	GPW	1943	7680	1
GEN PURPOSE WHSE	2565	Warehouse - Existing - Pre 1980	GPW	1942	18280	1
MAINT/STORAGE	2556	Warehouse - Existing - Pre 1980	GPW	1943	7680	1
NUTTER FIELD HOUSE	1067	Warehouse - Existing - Pre 1980	GPW	1942	25908	2
FE STORAGE	2219	Warehouse - Existing - Pre 1980	GPW	1942	960	1
FE STORAGE	2221	Warehouse - Existing - Pre 1980	GPW	1942	7680	1
FE STORAGE	2220	Warehouse - Existing - Pre 1980	GPW	1942	7680	1
RECYCLING FAC	2553_????	Warehouse - Existing - Pre 1980	GPW	1942	19780	2
KENNEL	2240	Warehouse - Existing - Pre 1980	GPW	1978	2366	1
BOOSTER PUMP BLDG	941	Warehouse Existing - 90.1 2007	GPW	2004	4263	1
Outdoor Adventure Center	2290	Warehouse Existing - 90.1 2007	GPW	2008	5000	1
RECYCLE CENTER	2549	Warehouse Existing - 90.1 2007	GPW	2007	11700	1
GAS CHAMBER	6035	Warehouse Existing - 90.1 2007	GPW	2009	5954	1

Base case facility list

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
ADMIN GEN PURP	401	Admin - existing - pre 1980 wood	BNHQ	1941	9567	2
CLASSROOM	975	Admin - existing - pre 1980 wood	BNHQ	1942	2500	1
CLASSROOM	978	Admin - existing - pre 1980 wood	BNHQ	1942	5310	1
OPERATION BR/WRK MGNT	2222	Admin - existing - pre 1980 wood	BNHQ	1942	7680	1
ADMIN GEN PUR	2204	Admin - existing - pre 1980 wood	BNHQ	1941	3525	1
ADMIN GEN PURP	2201	Admin - existing - pre 1980 wood	BNHQ	1941	2865	1
ADMIN GEN PURP	2202	Admin - existing - pre 1980 wood	BNHQ	1942	4005	1
BCOF	20131	AIT B/COF Planned	Training Barracks	2013	239665	5

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
BCOF	20132	AIT B/COF Planned	Training Barracks	2013	288990	5
ARMY RES CENTER	1350	ARC Existing - Post 1980	ARC	1987	18422	1
MAINT/STORAGE	1391	ARC Existing - Pre 1980	ARC	1967	2304	1
CTA at TA 183	1446	BdeHQ Existing - 90.1 2007	BdeHQ	2008	13264	1
3 CO FIRE STATION	580	BdeHQ Existing - Post 1980	BdeHQ	2000	17227	1
MP HQ/OPNS	1000	BdeHQ Existing - Post 1980	BdeHQ	1993	67434	1
DAVIDSON FITNESS CENTER	1300	BdeHQ Existing - Post 1980	BdeHQ	1994	75300	2
TELEVIDEO CENTER, HOGE	3200	BdeHQ Existing - Post 1980	BdeHQ	1989	139798	4
DISPATCH BLDG	5267	BdeHQ Existing - Post 1980	BdeHQ	1986	6012	1
COMPUTER CLASSROOM	708A	BdeHQ Existing - Post 1980	BdeHQ	2001	4325	1
CHAPLAIN ADMIN	590	BdeHQ Existing - Pre 1980	BdeHQ	1941	3263	2
BDE HQ BLDG	636	BdeHQ Existing - Pre 1980	BdeHQ	1964	9236	3
SHEA GYMNASIUM	640	BdeHQ Existing - Pre 1980	BdeHQ	1966	20425	1
BRIGADE HEADQUARTERS BLDG	741	BdeHQ Existing - Pre 1980	BdeHQ	1965	9236	3
SPECIAL PURPOSE CLASSROOM	746	BdeHQ Existing - Pre 1980	BdeHQ	1966	20425	1
BDE S-4	743	BdeHQ Existing - Pre 1980	BdeHQ	1966	3700	1
SWIFT GYM	826	BdeHQ Existing - Pre 1980	BdeHQ	1967	20425	1
BDE HEADQUARTERS	844	BdeHQ Existing - Pre 1980	BdeHQ	1967	9890	3
BDE HQ	1022	BdeHQ Existing - Pre 1980	BdeHQ	1971	6163	1
BDE HQ BLDG	1027	BdeHQ Existing - Pre 1980	BdeHQ	1971	11316	1
MUSEUM	1607	BdeHQ Existing - Pre 1980	BdeHQ	1970	75265	3
GYMNASIUM	1714	BdeHQ Existing - Pre 1980	BdeHQ	1979	16784	2
BN HQ BLDG	6100	BNHQ Existing - 90.1 2007	BNHQ	2010	23045	1
Community Center	N/A	BNHQ Existing - 90.1 2007	BNHQ	2013	7294	1
N/A	2134	BNHQ Existing - 90.1 2007	BNHQ	2013	13179	8
N/A	2132	BNHQ Existing - 90.1 2007	BNHQ	2013	4018	3
N/A	2133	BNHQ Existing - 90.1 2007	BNHQ	2013	2039	1
N/A	2131	BNHQ Existing - 90.1 2007	BNHQ	2013	3404	1
DPW ADMIN BLDG	2200B	BNHQ Existing - 90.1 2007	BNHQ	2010	5273	1
PRIME POWER SCHOOL	12630	BNHQ Existing - 90.1 2007	BNHQ	2010	48117	1
200 MAN CLASSROOM	894	BNHQ Existing - 90.1 2007	BNHQ	2008	6000	1
200 MAN CLASSROOM	912	BNHQ Existing - 90.1 2007	BNHQ	2009	6000	1
CBRN RESPONDER FACILITY	2130	BNHQ Existing - 90.1 2007	BNHQ	2007	39725	1
VISTOR CENTER, NORTH GATE	100	BNHQ Existing - Post 1980	BNHQ	2004	11742	1
GUARD BOOTH	101	BNHQ Existing - Post 1980	BNHQ	2005	607	1
SCHOOL/TRAINING CENTER	890	BNHQ Existing - Post 1980	BNHQ	1999	41676	2
GEN INST BLDG	2241	BNHQ Existing - Post 1980	BNHQ	2006	5048	1
APPL INST BLDG	12610	BNHQ Existing - Post 1980	BNHQ	1983	1800	1
CLASSROOM	5049A	BNHQ Existing - Post 1980	BNHQ	2006	2428	1
CLASSROOM	5049B	BNHQ Existing - Post 1980	BNHQ	2006	2428	1
GEN INST BLDG	5041	BNHQ Existing - Post 1980	BNHQ	2006	2501	1

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
SOLDIER SERVICE CENTER	470	BNHQ Existing - Post 1980	BNHQ	1995	101996	2
CID FACILITY	560	BNHQ Existing - Post 1980	BNHQ	1995	6281	1
INDOOR TRAINING	708	BNHQ Existing - Post 1980	BNHQ	1988	25600	1
750-MAN CLSRM	768	BNHQ Existing - Post 1980	BNHQ	1988	11500	1
DAVIS ENLISTED CLUB	805	BNHQ Existing - Post 1980	BNHQ	1984	17237	1
CLASSROOM	896	BNHQ Existing - Post 1980	BNHQ	2004	3690	1
CLASSROOM	964	BNHQ Existing - Post 1980	BNHQ	1999	9471	1
CLASSROOMS	961	BNHQ Existing - Post 1980	BNHQ	1999	37460	1
CLASSROOM	970	BNHQ Existing - Post 1980	BNHQ	1999	3441	1
CLASSROOMS	968	BNHQ Existing - Post 1980	BNHQ	1999	1452	1
CLASSROOMS	966	BNHQ Existing - Post 1980	BNHQ	1999	8007	1
CLASSROOM	963	BNHQ Existing - Post 1980	BNHQ	1999	9901	1
CLASSROOM	962	BNHQ Existing - Post 1980	BNHQ	1999	9394	1
BN HEADQUARTERS FOR 787MP	935	BNHQ Existing - Post 1980	BNHQ	2003	22917	1
CLASSROOM	971	BNHQ Existing - Post 1980	BNHQ	1999	23287	2
CLASSROOM	972	BNHQ Existing - Post 1980	BNHQ	1999	1000	1
CLASSROOM	974	BNHQ Existing - Post 1980	BNHQ	1999	1223	1
CLASSROOM	977	BNHQ Existing - Post 1980	BNHQ	1999	1742	2
CLASSROOM	976	BNHQ Existing - Post 1980	BNHQ	1999	1359	1
MTOC CLASSROOM	980	BNHQ Existing - Post 1980	BNHQ	1993	17630	1
CLASSROOM	973	BNHQ Existing - Post 1980	BNHQ	1999	1000	1
UNIT CHAPEL	1712	BNHQ Existing - Post 1980	BNHQ	1980	9050	1
RECEPTION FACILITY	2100	BNHQ Existing - Post 1980	BNHQ	1989	60844	1
ENGR ADM BLDG	2200	BNHQ Existing - Post 1980	BNHQ	2005	7238	1
ENTOMOLOGY FAC	2273	BNHQ Existing - Post 1980	BNHQ	1980	2800	1
MANSCEN NCOA HQ BLDG	3220	BNHQ Existing - Post 1980	BNHQ	1999	9106	1
CLASSROOM	3209	BNHQ Existing - Post 1980	BNHQ	2004	5940	1
GEN INST BLDG/LINCOLN	3201	BNHQ Existing - Post 1980	BNHQ	1989	146322	7
LIBRARY	3202	BNHQ Existing - Post 1980	BNHQ	1989	61000	7
GIF/THURMAN HALL	3203	BNHQ Existing - Post 1980	BNHQ	1999	288054	3
GEN INST BLDG	4191	BNHQ Existing - Post 1980	BNHQ	1982	2400	1
APPL INST BLDG	4190	BNHQ Existing - Post 1980	BNHQ	1980	2400	1
APPL INST BLDG	4194	BNHQ Existing - Post 1980	BNHQ	1986	1800	1
CLASSROOM	5046	BNHQ Existing - Post 1980	BNHQ	2001	2926	1
CLASSROOMS	5400	BNHQ Existing - Post 1980	BNHQ	1984	98932	3
CLSRM—TA 147	6022	BNHQ Existing - Post 1980	BNHQ	1986	1800	1
CLASSROOM	5080	BNHQ Existing - Post 1980	BNHQ	2005	3690	1
CLASSROOM	5081	BNHQ Existing - Post 1980	BNHQ	2005	3690	1
APPL INST BLDG	12710	BNHQ Existing - Post 1980	BNHQ	1983	1800	1
TRAINING BLDG	5101	BNHQ Existing - Post 1980	BNHQ	1999	49955	1
CLASSROOMS	5100	BNHQ Existing - Post 1980	BNHQ	1999	12321	1
GUARD HOUSE	5102	BNHQ Existing - Post 1980	BNHQ	1999	535	1

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
CLASSROOM	1394A	BNHQ Existing - Post 1980	BNHQ	2003	3240	1
APPL INST BLDG	5072	BNHQ Existing - Post 1980	BNHQ	1977	12400	1
ADMIN/CLSRM	5079	BNHQ Existing - Pre 1980	BNHQ	1976	1440	1
GEN INST BLDG	5077	BNHQ Existing - Pre 1980	BNHQ	1976	1440	1
ADMIN GEN PURP	315	BNHQ Existing - Pre 1980	BNHQ	1971	41707	4
ADMIN SPACE FOR MP-TASS	312	BNHQ Existing - Pre 1980	BNHQ	1965	23632	4
CLASSROOMS	320	BNHQ Existing - Pre 1980	BNHQ	1976	2617	1
DIAL CENTRAL OFC/ADMIN	404	BNHQ Existing - Pre 1980	BNHQ	1961	8516	1
POST CHAPEL	450	BNHQ Existing - Pre 1980	BNHQ	1962	12058	1
ARTS & CRAFTS CENTER	486	BNHQ Existing - Pre 1980	BNHQ	1977	14800	1
TRUMAN ED CTR	499	BNHQ Existing - Pre 1980	BNHQ	1975	39424	1
MAIN POST OFFICE	498	BNHQ Existing - Pre 1980	BNHQ	1964	30414	2
CARLSON TRAVEL	496	BNHQ Existing - Pre 1980	BNHQ	1968	1800	1
BN HQ BLDG	625	BNHQ Existing - Pre 1980	BNHQ	1965	6163	1
3 TNG BDE S-4	633	BNHQ Existing - Pre 1980	BNHQ	1963	12134	1
POST SAFETY OFFICE	631	BNHQ Existing - Pre 1980	BNHQ	1965	6163	1
UNIT CHAPEL	637	BNHQ Existing - Pre 1980	BNHQ	1964	8949	1
ADMIN GEN PURP	606	BNHQ Existing - Pre 1980	BNHQ	1965	11302	1
CLASSROOM	638	BNHQ Existing - Pre 1980	BNHQ	1965	3700	1
BAKER THEATER	607	BNHQ Existing - Pre 1980	BNHQ	1968	17086	3
BN HQ BLDG	658	BNHQ Existing - Pre 1980	BNHQ	1965	6163	1
BN HQS	732	BNHQ Existing - Pre 1980	BNHQ	1965	3795	1
CLASSROOM	749	BNHQ Existing - Pre 1980	BNHQ	1965	13280	1
UNIT CHAPEL	742	BNHQ Existing - Pre 1980	BNHQ	1966	8949	1
BN HQ BLDG	740	BNHQ Existing - Pre 1980	BNHQ	1965	6163	1
BN HQ BLDG	753	BNHQ Existing - Pre 1980	BNHQ	1965	6163	1
CLASSROOM	786	BNHQ Existing - Pre 1980	BNHQ	1960	9160	1
BN HQ BLDG	822	BNHQ Existing - Pre 1980	BNHQ	1966	6163	1
BN HQ BLDG	825	BNHQ Existing - Pre 1980	BNHQ	1966	6163	1
S4 ADMIN OFFICE	832	BNHQ Existing - Pre 1980	BNHQ	1967	3702	1
ABRAMS THEATRE	804	BNHQ Existing - Pre 1980	BNHQ	1972	17086	1
BAND TNG FAC	837	BNHQ Existing - Pre 1980	BNHQ	1967	13280	1
CLASSROOM	852	BNHQ Existing - Pre 1980	BNHQ	1966	2400	1
CLASSROOM	851	BNHQ Existing - Pre 1980	BNHQ	1966	2400	1
HQ - NAVY DET	838	BNHQ Existing - Pre 1980	BNHQ	1967	6163	1
ADMIN SPACE FOR MARINE	841	BNHQ Existing - Pre 1980	BNHQ	1967	12155	1
MARINES HQ	842	BNHQ Existing - Pre 1980	BNHQ	1967	6163	1
UNIT CHAPEL	843	BNHQ Existing - Pre 1980	BNHQ	1967	8890	2
ADMIN GEN PURP	1018	BNHQ Existing - Pre 1980	BNHQ	1971	3700	1
BN HQ BLDG	1009	BNHQ Existing - Pre 1980	BNHQ	1970	6163	1
CLASSROOM/ADMIN	1008	BNHQ Existing - Pre 1980	BNHQ	1970	6163	1
BN ADMIN & CLRM	1023	BNHQ Existing - Pre 1980	BNHQ	1971	6163	1
CLASSROOM	1134	BNHQ Existing - Pre 1980	BNHQ	1960	9160	1

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
GEN INST BLDG	1230	BNHQ Existing - Pre 1980	BNHQ	1960	9160	1
INSTRUCTION BLDG	1599	BNHQ Existing - Pre 1980	BNHQ	1966	2400	1
BOWLING CENTER	1609	BNHQ Existing - Pre 1980	BNHQ	1972	37354	1
ADMIN SPACE FOR MARINE	1702	BNHQ Existing - Pre 1980	BNHQ	1978	23411	1
ADMIN SPACE	1703	BNHQ Existing - Pre 1980	BNHQ	1978	19096	1
ADMIN GEN PURP	1705	BNHQ Existing - Pre 1980	BNHQ	1978	23411	1
BN HQ BLDG	1704	BNHQ Existing - Pre 1980	BNHQ	1978	9548	1
CLASSROOM FOR MARINES	1721	BNHQ Existing - Pre 1980	BNHQ	1978	2002	1
ADMIN AREA FOR MARINES	1772	BNHQ Existing - Pre 1980	BNHQ	1979	2002	1
CLASSROOM FOR MARINES	1760	BNHQ Existing - Pre 1980	BNHQ	1978	2002	1
ADMIN AREA FOR NAVY	1770	BNHQ Existing - Pre 1980	BNHQ	1978	2002	1
CALL FOR FIRE CLASSROOM	1750	BNHQ Existing - Pre 1980	BNHQ	1978	12929	1
DPW ADMIN BLDG	2224	BNHQ Existing - Pre 1980	BNHQ	1979	2024	1
APPL INST BLDG	5059	BNHQ Existing - Pre 1980	BNHQ	1967	6600	1
APPL INST BLDG	5049	BNHQ Existing - Pre 1980	BNHQ	1970	3840	1
APPL INST BLDG	5048	BNHQ Existing - Pre 1980	BNHQ	1970	3840	1
APPL INST BLDG	5047	BNHQ Existing - Pre 1980	BNHQ	1970	3840	1
CLASSROOM	5042	BNHQ Existing - Pre 1980	BNHQ	1951	2872	1
GEN INST BLDG	5076	BNHQ Existing - Pre 1980	BNHQ	1977	1000	1
GEN INST BLDG	5075	BNHQ Existing - Pre 1980	BNHQ	1976	1440	1
DIRECTOR'S OFFICE	2200A	BNHQ Existing - Pre 1980	BNHQ	1966	3504	1
ENL BK W/O DIN	318	BNHQ Existing - Pre 1980	BNHQ	1976	12174	3
ENL BK W/O DIN	319	BNHQ Existing - Pre 1980	BNHQ	1976	12174	3
ADMIN GEN PURPOSE	2226	BNHQ Existing - Pre 1980	BNHQ	1977	3504	1
BN HQ BLDG	750	BNHQ Existing - Pre 1980	BNHQ	1965	6106	1
INDOOR CLASSROOM	1445	BNHQ Existing - Pre 1980	BNHQ	1961	9855	1
CLASSROOMS FOR AIR FORCE	1006	BNHQ Existing - Pre 1980	BNHQ	1970	12132	1
ADMIN	1706	BNHQ Existing - Pre 1980	BNHQ	1978	23437	1
GAME WARDEN & ANIMAL CONT	1614	BNHQ Existing - Pre 1980	BNHQ	1961	2596	1
VET FACILITY	2399	BNHQ Existing - Pre 1980	BNHQ	1964	6011	1
Battalion HQ	N/A	BNHQ Planned - 90.1 2007	BNHQ	2013	31169	1
Battalion HQ	6140	BNHQ Planned - 90.1 2007	BNHQ	2013	31169	1
Battalion HQ	N/A	BNHQ Planned - 90.1 2007	BNHQ	2013	21473	1
Battalion HQ	N/A	BNHQ Planned - 90.1 2007	BNHQ	2013	21473	1
CDC SCHOOL AGE	616	CDC Existing - 90.1 2007	CDC	2009	23576	1
CHILD DEVELOPMENT CENTER	615	CDC Existing - Post 1980	CDC	1995	24500	1
ARNG ARMORY	986	COF Existing - Post 1980	COF	1997	30192	1
HQS PART OF BLDG	2107	COF Existing - Post 1980	COF	2001	26900	3
HQS PART OF BLDG	2109	COF Existing - Post 1980	COF	2001	49763	3
HQS PART OF BLDG	2108	COF Existing - Post 1980	COF	2001	49763	3
CO HQ BLDG	2113	COF Existing - Post 1980	COF	2005	2741	1
ADM & SUP BLDG	626	COF Existing - Pre 1980	COF	1964	12155	1

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COMPANY HEADQUARTERS	734	COF Existing - Pre 1980	COF	1965	12155	1
CO HQ BLDG	733	COF Existing - Pre 1980	COF	1965	12155	1
CO HQ BLDG	751	COF Existing - Pre 1980	COF	1966	12155	1
ADM & SUP BLDG (A, B & D)	752	COF Existing - Pre 1980	COF	1966	12156	1
ADM & SUP BLDG	823	COF Existing - Pre 1980	COF	1966	12155	1
CO HQ BLDG	824	COF Existing - Pre 1980	COF	1966	12155	1
STORAGE	840	COF Existing - Pre 1980	COF	1967	7152	1
ADM & SUP BLDG	1007	COF Existing - Pre 1980	COF	1970	12155	1
ADM & SUP BLDG	1025	COF Existing - Pre 1980	COF	1971	12155	1
ADM & SUP BLDG	1701	COF Existing - Pre 1980	COF	1978	23411	1
CO HQ BLDG	1707	COF Existing - Pre 1980	COF	1979	14047	1
B/COF	N/A	COF Planned - 90.1 2007	COF	2013	26883	1
DBL DINNING FACILITY	6111	DFAC Existing - 90.1 2007	DFAC	2011	62234	1
DINING FACILITY	930	DFAC Existing - Post 1980	DFAC	2004	34789	1
GRANT HALL DINING	2105	DFAC Existing - Post 1980	DFAC	1990	16856	1
UPEH DINING FACILITY	3223	DFAC Existing - Post 1980	DFAC	1999	20580	1
ENL PERS DINE	630	DFAC Existing - Pre 1980	DFAC	1964	13280	1
ENL PERS DINE	735	DFAC Existing - Pre 1980	DFAC	1965	13280	1
ENL PERS DINE	739	DFAC Existing - Pre 1980	DFAC	1965	13280	1
ENL PERS DINE	754	DFAC Existing - Pre 1980	DFAC	1966	13280	1
ENL PERS DINE	821	DFAC Existing - Pre 1980	DFAC	1966	13280	1
ENL PERS DINE	820	DFAC Existing - Pre 1980	DFAC	1966	13280	1
ENL PERS DINE, EDP	836	DFAC Existing - Pre 1980	DFAC	1967	13280	1
ENL PERS DINE, EDP	1010	DFAC Existing - Pre 1980	DFAC	1971	11316	1
ENL PERS DINE, EDP	1011	DFAC Existing - Pre 1980	DFAC	1970	11316	1
ENL PERS DINE, EDP	1740	DFAC Existing - Pre 1980	DFAC	1979	22919	1
ENL PERS DINE	5073	DFAC Existing - Pre 1980	DFAC	1952	9600	1
DINING FACILITY	N/A	DFAC Planned - 90.1 2007	DFAC	2013	27263	1
Dining Facility	N/A	DFAC Planned - 90.1 2007	DFAC	2013	38866	1
Double Dining Facility	N/A	DFAC Planned - 90.1 2007	DFAC	2013	38865	1
Large Chapel Complex	N/A	Religious Existing - 90.1 2007	Religious	2013	27463	1
VEH MAINT SHOP	5262	TEMF Existing - Post 1980	TEMF	2006	8522	1
STORAGE	5263	TEMF Existing - Post 1980	TEMF	2002	5549	1
FORKLIFT TNG CLASSROOM	663	TEMF Existing - Post 1980	TEMF	1982	12834	2
MAINTENANCE FACILITY	897	TEMF Existing - Post 1980	TEMF	2005	3600	1
CATF WAREHOUSE	895	TEMF Existing - Post 1980	TEMF	1999	13900	1
VEHICLE MNT SH ORG-MTOC	950	TEMF Existing - Post 1980	TEMF	1994	26834	2
READY BLDG/WWD BLDG	1270	TEMF Existing - Post 1980	TEMF	2003	12300	1
GEN INST BLDG-KIMBRO HALL	12700	TEMF Existing - Post 1980	TEMF	1987	23880	1
ROBOTIC TECH/MAINT	1590	TEMF Existing - Post 1980	TEMF	1994	2250	1
43D AGBN S-4	2110	TEMF Existing - Post 1980	TEMF	2001	4412	1
RAILROAD AMINT BLDG	2231	TEMF Existing - Post 1980	TEMF	2003	1560	1
MAINT SHOP-TRAIN	2230	TEMF Existing - Post 1980	TEMF	1994	3600	1

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
SUPPLY STORE	2346	TEMF Existing - Post 1980	TEMF	1941	10500	1
STORAGE	2550	TEMF Existing - Post 1980	TEMF	2003	5200	1
BATTERY SHOP	5265	TEMF Existing - Post 1980	TEMF	1985	199353	1
STORAGE MP EQUIPMENT	5264	TEMF Existing - Post 1980	TEMF	2000	3600	1
RANGE SUPPORT BLDG	12740	TEMF Existing - Post 1980	TEMF	1998	320	1
VEH MNT SH ORG	5069	TEMF Existing - Post 1980	TEMF	1980	13000	1
APPL INST BLDG-KAWAMURA	5074	TEMF Existing - Post 1980	TEMF	1981	32044	1
SUPPORT BUILDING	12705	TEMF Existing - Post 1980	TEMF	2002	4368	1
K-SPAN	5079A	TEMF Existing - Post 1980	TEMF	2003	4992	1
VEH PAINT/AUTO BODY SHOP	5266	TEMF Existing - Post 1980	TEMF	1986	7560	1
APPL INST BLDG	5051	TEMF Existing - Pre-1980	TEMF	1966	7680	1
FE STOREHOUSE	599	TEMF Existing - Pre-1980	TEMF	1941	18270	1
STORAGE	632	TEMF Existing - Pre-1980	TEMF	1963	13280	1
VEH MNT SH ORG	672	TEMF Existing - Pre-1980	TEMF	1964	4786	1
VEH MNT SHOP	680	TEMF Existing - Pre-1980	TEMF	1964	4786	1
VEH MNT SH ORG	681	TEMF Existing - Pre-1980	TEMF	1964	4786	1
VEH MNT SH ORG	773	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	772	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	780	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	781	TEMF Existing - Pre-1980	TEMF	1966	4786	1
STORAGE SPACE	8208	TEMF Existing - Pre-1980	TEMF	1971	3648	1
VEH MNT SH ORG	872	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	873	TEMF Existing - Pre-1980	TEMF	1966	4786	1
MAINT BUILDING	880	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	881	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	991	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	998	TEMF Existing - Pre-1980	TEMF	1966	4786	1
LAWNMOWER REPAIR SHOP	1549	TEMF Existing - Pre-1980	TEMF	1960	9479	1
VEH MNT SH ORG	999	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	990	TEMF Existing - Pre-1980	TEMF	1966	4786	1
VEH MNT SH ORG	1390	TEMF Existing - Pre-1980	TEMF	1977	10550	1
AUTO CRAFTS SHOP	1383	TEMF Existing - Pre-1980	TEMF	1973	8840	1
MAINTENANCE/ADMIN	1588	TEMF Existing - Pre-1980	TEMF	1941	3108	1
VEH MAINT SHOP	2250	TEMF Existing - Pre-1980	TEMF	1977	1862	1
ADM & SUP BLDG	2314	TEMF Existing - Pre-1980	TEMF	1941	9267	2
STORAGE, EDP OFFICE	2318	TEMF Existing - Pre-1980	TEMF	1941	9267	1
TRAINING	2385	TEMF Existing - Pre-1980	TEMF	1941	3203	1
STORAGE	4199	TEMF Existing - Pre-1980	TEMF	1963	2400	1
CAR RENTAL	2555	TEMF Existing - Pre-1980	TEMF	1941	3108	1
APPL INST BLDG	5056	TEMF Existing - Pre-1980	TEMF	1967	1836	1
APPL INST BLDG	5052	TEMF Existing - Pre-1980	TEMF	1966	14480	2
VEH MNT SH ORG	5053	TEMF Existing - Pre-1980	TEMF	1966	29225	1
APPL INST BLDG	5050	TEMF Existing - Pre-1980	TEMF	1966	7436	1

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
VEH MNT SH ORG	5071	TEMF Existing - Pre-1980	TEMF	1952	9594	1
APPL INST	5070	TEMF Existing - Pre-1980	TEMF	1976	14400	1
TERMINAL EQUIPMENT BLDG	435	TEMF Existing - Pre-1980	TEMF	1959	1757	1
COMB AC HT BLDG	745	TEMF Existing - Pre-1980	TEMF	1965	4665	1
N/A	745A	TEMF Existing - Pre-1980	TEMF	2013	2156	1
COMB AC HT BLDG	1021	TEMF Existing - Pre-1980	TEMF	1971	6163	1
WATER TRMT BLDG	1601	TEMF Existing - Pre-1980	TEMF	1941	7664	1
HEAT PLANT BLDG	2369	TEMF Existing - Pre-1980	TEMF	1978	13757	2
CATF WAREHOUSE	898	TEMF Existing 90.1 2007	TEMF	2010	14547	1
DOL CENTRAL RECEIVING	2562A	TEMF Existing 90.1 2007	TEMF	2010	4953	1
TEMPORARILY 4TH MEB	2333	TEMF Existing 90.1 2007	TEMF	2009	4783	1
DOL CENTRAL RECEIVING WAREHSE	2562	TEMF Existing 90.1 2007	TEMF	2009	4783	1
RG SPT FAC	12742	TEMF Existing 90.1 2007	TEMF	2010	6800	1
RG SPT FAC	12741	TEMF Existing 90.1 2007	TEMF	2010	6800	1
Lawn Mtce Bldg	6106	TEMF Existing 90.1 2007	TEMF	2010	2652	1
TRAINEE BARRACKS	2113D	Trainee Barracks Existing - Post 1980	Training Barracks	2005	2912	1
TRAINEE BARRACKS	2113F	Trainee Barracks Existing - Post 1980	Training Barracks	2005	2912	1
TRAINEE BARRACKS	2113E	Trainee Barracks Existing - Post 1980	Training Barracks	2005	2912	1
TRAINEE BARRACKS	2113C	Trainee Barracks Existing - Post 1980	Training Barracks	2005	2912	1
TRAINEE BARRACKS	2113A	Trainee Barracks Existing - Post 1980	Training Barracks	2005	2912	1
N/A	2113B	Trainee Barracks Existing - Post 1980	Training Barracks	2005	2912	1
AIT B/COF	N/A	Training Barracks - Existing - 90.1 2007	Training Barracks	2013	106000	3
AIT B/COF	N/A	Training Barracks - Existing - 90.1 2007	Training Barracks	2013	106000	3
AIT B/COF	N/A	Training Barracks - Existing - 90.1 2007	Training Barracks	2013	106000	3
TRAINEE BARRACKS	932	Training Barracks - Existing - 90.1 2007	Training Barracks	2004	55660	3
TRAINEE BARRACKS	934	Training Barracks - Existing - 90.1 2007	Training Barracks	2004	55660	3
BARRACKS	936	Training Barracks - Existing - 90.1 2007	Training Barracks	2004	55660	3
BARRACKS	937	Training Barracks - Existing - 90.1 2007	Training Barracks	2004	55660	3
TRAINEE BARRACKS	939	Training Barracks - Existing - 90.1 2007	Training Barracks	2004	55660	3
B/COF	N/A	Training Barracks - Existing - 90.1 2007	Training Barracks	2013	55660	3
B/COF	N/A	Training Barracks - Existing - 90.1 2007	Training Barracks	2013	55600	3

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
BCOF - Trainee Barracks	6103	Training Barracks - Existing - 90.1 2007	Training Barracks	2010	55600	3
BCOF - Trainee Barracks	6104	Training Barracks - Existing - 90.1 2007	Training Barracks	2010	55600	3
BCOF - Trainee Barracks	6102	Training Barracks - Existing - 90.1 2007	Training Barracks	2010	55600	3
BCOF - Trainee Barracks	6101	Training Barracks - Existing - 90.1 2007	Training Barracks	2010	55600	3
AIT B/COF	N/A	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	106000	3
B/COF	N/A	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	N/A	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	N/A	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	6147	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	6143	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	6142	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	6146	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	6141	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	6105	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	N/A	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	N/A	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	N/A	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	N/A	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	N/A	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	N/A	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	N/A	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	N/A	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
B/COF	N/A	Training Barracks - Planned - 90.1 2007	Training Barracks	2013	55600	3
ENL BKS BASIC TRAINING	628	Training Barracks Existing - Pre 1980	Training Barracks	1964	40640	3
ENL BKS BASIC TRAINING	627	Training Barracks Existing - Pre 1980	Training Barracks	1964	40640	3

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ENL BKS BASIC TRAINING	629	Training Barracks Existing - Pre 1980	Training Barracks	1964	40640	3
ENL BKS BASIC TRAINING	635	Training Barracks Existing - Pre 1980	Training Barracks	1963	40990	3
TRAINEE BKS	634	Training Barracks Existing - Pre 1980	Training Barracks	1963	40990	3
ENL BKS OSUT	757	Training Barracks Existing - Pre 1980	Training Barracks	1966	40640	3
ENL BKS OSUT	737	Training Barracks Existing - Pre 1980	Training Barracks	1965	40640	3
ENL BKS AIT	756	Training Barracks Existing - Pre 1980	Training Barracks	1966	40640	3
ENL BKS AIT	755	Training Barracks Existing - Pre 1980	Training Barracks	1966	40640	3
ENL BKS OSUT	747	Training Barracks Existing - Pre 1980	Training Barracks	1965	40640	3
ENL BKS OSUT	748	Training Barracks Existing - Pre 1980	Training Barracks	1965	40640	3
ENL BKS OSUT	738	Training Barracks Existing - Pre 1980	Training Barracks	1965	40640	3
ENL BKS BASIC TRAINING	736	Training Barracks Existing - Pre 1980	Training Barracks	1965	40640	3
ENL BKS BASIC TRAINING	730	Training Barracks Existing - Pre 1980	Training Barracks	1965	40640	3
ENL BKS BASIC TRAINING	731	Training Barracks Existing - Pre 1980	Training Barracks	1965	40640	3
BATH HOUSE	604	Training Barracks Existing - Pre 1980	Training Barracks	1961	4918	1
ENL BKS OSUT	1014	Training Barracks Existing - Pre 1980	Training Barracks	1970	40639	3
ENL BKS OSUT	1016	Training Barracks Existing - Pre 1980	Training Barracks	1971	40639	3
ENL BKS OSUT	1013	Training Barracks Existing - Pre 1980	Training Barracks	1970	40639	3
ENL BKS OSUT	1015	Training Barracks Existing - Pre 1980	Training Barracks	1971	40639	3
ENL BKS OSUT	1012	Training Barracks Existing - Pre 1980	Training Barracks	1970	40639	3
ENL BKS OSUT	1029	Training Barracks Existing - Pre 1980	Training Barracks	1971	40639	3
ENL BKS OSUT	1028	Training Barracks Existing - Pre 1980	Training Barracks	1971	40640	3
ITRO STUDENTS, AIR FORCE	1729	Training Barracks Existing - Pre 1980	Training Barracks	1978	24664	3
PERM PARTY BKS, 1 ENG BDE	1731	Training Barracks Existing - Pre 1980	Training Barracks	1979	11343	3
BARRACKS	1720	Training Barracks Existing - Pre 1980	Training Barracks	1978	24644	3
RESERVE COMP BARRACKS	1724	Training Barracks Existing - Pre 1980	Training Barracks	1978	11232	3

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
ITRO TRAINEE BKS, AIR FOR	1728	Training Barracks Existing - Pre 1980	Training Barracks	1979	24664	3
BARRACKS, MED HOLD	1723	Training Barracks Existing - Pre 1980	Training Barracks	1978	24644	3
ENLISTED UPH	1732	Training Barracks Existing - Pre 1980	Training Barracks	1979	11343	3
ENL PERM PARTY, 577 ENG	1735	Training Barracks Existing - Pre 1980	Training Barracks	1979	24664	3
PERM PARTY, ITRO	1733	Training Barracks Existing - Pre 1980	Training Barracks	1979	11343	3
ENL PERM PARTY	1734	Training Barracks Existing - Pre 1980	Training Barracks	1979	24664	3
MARINE ITRO BARRACKS	1726	Training Barracks Existing - Pre 1980	Training Barracks	1979	11343	3
PERM PARTY BARRACKS	1730	Training Barracks Existing - Pre 1980	Training Barracks	1978	11343	3
ITRO TRAINEE BKS, AIR FOR	1725	Training Barracks Existing - Pre 1980	Training Barracks	1978	11343	3
RESERVE COMP BARRACKS	1722	Training Barracks Existing - Pre 1980	Training Barracks	1978	11343	3
ITRO TRAINEE BKS, MARINES	1765	Training Barracks Existing - Pre 1980	Training Barracks	1978	24664	3
ITRO TRAINEE BKS, MARINES	1764	Training Barracks Existing - Pre 1980	Training Barracks	1978	11343	3
ITRO TRAINEE BKS, MARINES	1775	Training Barracks Existing - Pre 1980	Training Barracks	1979	11343	3
ITRO TRAINEE BKS, MARINE	1774	Training Barracks Existing - Pre 1980	Training Barracks	1979	11343	3
ITRO TRAINEE BKS, MARINES	1763	Training Barracks Existing - Pre 1980	Training Barracks	1978	11343	3
MARINE ITRO BARRACKS	1773	Training Barracks Existing - Pre 1980	Training Barracks	1979	24664	3
ITRO TRAINEE BKS, MARINES	1767	Training Barracks Existing - Pre 1980	Training Barracks	1978	24664	3
ITRO TRAINEE BKS, MARINES	1761	Training Barracks Existing - Pre 1980	Training Barracks	1978	24664	3
ITRO TRAINEE BKS, MARINE	1771	Training Barracks Existing - Pre 1980	Training Barracks	1979	11343	3
ITRO TRAINEE BKS, MARINE	1769	Training Barracks Existing - Pre 1980	Training Barracks	1978	24664	3
ITRO TRAINEE BKS, MARINES	1762	Training Barracks Existing - Pre 1980	Training Barracks	1978	11343	3
ITRO TRAINEE BKS, NAVY	1766	Training Barracks Existing - Pre 1980	Training Barracks	1978	11343	3
ITRO TRAINEE BKS, NAVY	1768	Training Barracks Existing - Pre 1980	Training Barracks	1978	11343	3
ITRO TRAINEE BKS, MARINES	1776	Training Barracks Existing - Pre 1980	Training Barracks	1979	24664	3
DET DAY ROOM	1736	Training Barracks Existing - Pre 1980	Training Barracks	1978	2002	1

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
DET DAY ROOM	1727	Training Barracks Existing - Pre 1980	Training Barracks	1978	2002	1
DET LATRINE/SHOWER BLDG	688	Training Barracks Existing - Pre 1980	Training Barracks	1966	2354	1
ENL BKS OSUT	817	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1966	40640	3
ENL BKS OSUT	818	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1966	40640	3
ENL BKS OSUT	819	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1966	40640	3
ENL BKS OSUT	816	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1966	40640	3
ENL BKS OSUT	815	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1966	40640	3
ENL BKS OSUT	831	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1967	40640	3
ENL BKS OSUT	830	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1967	40640	3
ENL BKS OSUT	829	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1967	40640	3
ENL BKS OSUT	828	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1967	40640	3
ENL BKS AIT	827	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1967	40640	3
FE MAINT SHOP	2212	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1942	8352	1
LUM & P SHED FE	2214	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1943	5184	1
LUM & P SHED FE	2213	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1943	4998	1
ADMIN GEN PURP/STORAGE	2208	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1942	8352	1
CARPENTER SHOP/LOCKSMITH	2216	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1942	4608	2
CARPENTER SHOP	2215	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1942	6144	1
WORK CONTROL SECTION	2203	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1941	2434	1
SIGN SHOP	2217	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1942	3200	1
FE MAINT SHOP	2207	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1942	3200	1
FE MAINT SHOP (PLUMBING)	2227	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1970	640	1
DET LATRINE/SHOWER BLDG	853	Training Barracks Existing - Pre-1980 Renovated	Training Barracks	1966	2400	1
Enlisted UPH	1954	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1952	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1953	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1955	UEPH Existing	UEPH	2009	2536	1

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
Enlisted UPH	1957	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1931	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1950	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1951	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1926	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1925	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1922	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1923	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1921	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1924	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1920	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1959	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1956	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1918	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1916	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1919	UEPH Existing	UEPH	2008	2536	1
Enlisted UPH	1913	UEPH Existing	UEPH	2008	2537	1
Enlisted UPH	1914	UEPH Existing	UEPH	2008	2536	1
Enlisted UPH	1917	UEPH Existing	UEPH	2008	2536	1
Enlisted UPH	1915	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1911	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1909	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1907	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1904	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1912	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1910	UEPH Existing	UEPH	2008	2540	1
Enlisted UPH	1908	UEPH Existing	UEPH	2008	2536	1
Enlisted UPH	1902	UEPH Existing	UEPH	2008	2535	1
Enlisted UPH	1900	UEPH Existing	UEPH	2008	2534	1
Enlisted UPH	1901	UEPH Existing	UEPH	2008	2533	1
Enlisted UPH	1906	UEPH Existing	UEPH	2008	2536	1
Enlisted UPH	1960	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1940	UEPH Existing	UEPH	2009	2534	1
Enlisted UPH	1942	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1944	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1946	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1948	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1947	UEPH Existing	UEPH	2009	2534	1
Enlisted UPH	1945	UEPH Existing	UEPH	2009	2534	1
Enlisted UPH	1943	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1941	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1961	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1964	UEPH Existing	UEPH	2009	2535	1

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
Enlisted UPH	1965	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1966	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1968	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1969	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1967	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1962	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1938	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1936	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1939	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1937	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1934	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1932	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1930	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1935	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1933	UEPH Existing	UEPH	2009	2536	1
Enlisted UPH	1963	UEPH Existing	UEPH	2009	2535	1
Enlisted UPH	1958	UEPH Existing	UEPH	2009	2535	1
Warrior in Transition	N/A	UEPH Planned - ASHRAE 90.1 2007	UEPH	2013	5866	1
Warrior in Transition	N/A	UEPH Planned - ASHRAE 90.1 2007	UEPH	2013	6316	1
Warrior in Transition	N/A	UEPH Planned - ASHRAE 90.1 2007	UEPH	2013	11065	1
LUM & P SHED FE	3301	Warehouse Existing - post 1980 Metal Building	GPW	1983	2556	1
LUM & P SHED FE	3302	Warehouse Existing - post 1980 Metal Building	GPW	1983	2861	1
LUM & P SHED FE	3300	Warehouse Existing - post 1980 Metal Building	GPW	1982	2592	1
FE STORAGE	2313	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
CLOTHING ISSUE	2324	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
GENERAL PURPSE WHSE	2334	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
GEN PURPOSE WHSE	2345	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
GEN PURPOSE WHSE	2344	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
BIN WHSE	2337	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
FE STOREHOUSE	2315	Warehouse - Existing - Pre 1980	GPW	1942	9000	1
STORAGE	2342	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
GENERAL PURPSE WHSE	2335	Warehouse - Existing - Pre 1980	GPW	1941	9267	2

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
WHSE	2341	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
BIN WHSE	2336	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
STORAGE, U-STORE-IT	2343	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
CLOTHING WHSE	2323	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
CLOTHING ISSUE	2322	Warehouse - Existing - Pre 1980	GPW	1941	11246	1
CLOTHING WHSE	2321	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
CLOTHING ISSUE/WHSE	2339	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
CLOTHING ISSUE/WHSE	2338	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
FE STORAGE	2319	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
CLOTHING ISSUE	2320	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
WHSE	2340	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
STORAGE	2303	Warehouse - Existing - Pre 1980	GPW	1941	1625	1
STORAGE	2330	Warehouse - Existing - Pre 1980	GPW	1941	9324	1
EXCH WAREHOUSE	2331	Warehouse - Existing - Pre 1980	GPW	1941	9266	2
GEN PURPOSE WHSE	2310	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
GEN STOREHOUSE	2325	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
GEN PURPOSE WHSE	2311	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
GEN PURPOSE WHSE	2326	Warehouse - Existing - Pre 1980	GPW	1941	9267	2
EXCHANGE WAREHOUSE	2332	Warehouse - Existing - Pre 1980	GPW	1941	9267	1
ENVIRON STORAGE	2307	Warehouse - Existing - Pre 1980	GPW	1941	1625	1
STORAGE	2306	Warehouse - Existing - Pre 1980	GPW	1941	1625	1
STORAGE	2305	Warehouse - Existing - Pre 1980	GPW	1941	1625	1
HAZMAT STOR/WEAPONS STOR	2308	Warehouse - Existing - Pre 1980	GPW	1941	15275	2
STORAGE AREA FOR 577	2304	Warehouse - Existing - Pre 1980	GPW	1941	1955	1
MAINT/STORAGE	2558	Warehouse - Existing - Pre 1980	GPW	1941	3108	1

Name	Number	Facility Group	Facility Type	Const'n Date	Conditioned Area (sq ft)	Floors
MAINT/STORAGE	2557	Warehouse - Existing - Pre 1980	GPW	1943	7680	1
GEN PURPOSE WHSE	2565	Warehouse - Existing - Pre 1980	GPW	1942	18280	1
MAINT/STORAGE	2556	Warehouse - Existing - Pre 1980	GPW	1943	7680	1
NUTTER FIELD HOUSE	1067	Warehouse - Existing - Pre 1980	GPW	1942	25908	2
FE STORAGE	2219	Warehouse - Existing - Pre 1980	GPW	1942	960	1
FE STORAGE	2221	Warehouse - Existing - Pre 1980	GPW	1942	7680	1
FE STORAGE	2220	Warehouse - Existing - Pre 1980	GPW	1942	7680	1
RECYCLING FAC	2553_????	Warehouse - Existing - Pre 1980	GPW	1942	19780	2
KENNEL	2240	Warehouse - Existing - Pre 1980	GPW	1978	2366	1
BOOSTER PUMP BLDG	941	Warehouse Existing - 90.1 2007	GPW	2004	4263	1
Outdoor Adventure Center	2290	Warehouse Existing - 90.1 2007	GPW	2008	5000	1
RECYCLE CENTER	2549	Warehouse Existing - 90.1 2007	GPW	2007	11700	1
GAS CHAMBER	6035	Warehouse Existing - 90.1 2007	GPW	2009	5954	1

Appendix C: Metering Evaluation Site Visit

Fort Leonard Wood
Metering Evaluation Site Visit
David Underwood
29-30 January, 2013

Principal participants

- Dave Underwood (ERDC-CERL, Mechanical Engineer) David.M.Underwood@usace.armymil
- Allen Simpson (FLW Energy Manager) allen.w.simpson2.civ@mail.mil
- Dallas Wheat (Honeywell) Dallas.Wheat@Honeywell.com
- David Shockley (Omega Pipeline) dshockley@omegapipeline.com
- Jeannie Elseman (DPW Utility Program Manager) jeqnnie.m.elseman.civ@mail.mil
- Terry Rosenthal (Laclede Electric Cooperative) trosenthal@lacledeelectric.com

Background

Fort Leonard Wood has several meter systems and ways of collecting metering data. Additional meters continue to be installed. It is desired to merge these various systems into one and ensure that future meters are installed such that they are compatible with the data collection scheme.

Existing conditions

Fort Leonard Wood has five different sources of meter data:

- **Laclede Electric** - They have approximately 224 advance meters that they collect data on. The memory registers are read, as opposed to older meters which typically have a pulse output. Terry is fairly sure that in order to get a pulse output from these smart meters the current AMI smart module would have to be removed. All smart electric meters are at least 30 feet from the building due to force protection requirements. Running communication wiring to the nearest controller or BPOC is problematic due to the large number of unmarked underground utilities. It may be cheaper/easier to install a separate meter inside the building and provide either a pulse output or LON digital communication. The data is transmitted via a mesh network on the unlicensed 900 MHz band via collectors to a tower and transmitted from the tower to Laclede's office in Lebanon via fiber. The information is processed from an XML schema into Laclede's database called Tantalas. Fort Leonard Wood can log into their system to look at data and can download the data into a ***text file***.

- **Omega Pipeline** - They have approximately 158 advance meters that they collect data on. The information is transmitted by a wireless GSM/GPRS modem to an Omega front end via an e-mail message which processes the messages into ***excel spreadsheet .xlsx files.*** Fort Leonard Wood receives these monthly (sometimes combined months) with ft^3 readings for each meter. Reported readings are cumulative on the hour. These meters also have a pulse output which could be read by the building's DDC, either a controller or a Building Point of Connection (BPOC) device. This is how Honeywell reads gas meters. With only a few exceptions, all gas meters are very close to the building and the building has DDC.
- **Honeywell** - They either have or soon will have a total of 32 electric meters and 14 gas meters hooked into the Honeywell system front end (EBI) as part of an ESPC project. This is a LON based system. They have the capability to provide Fort Leonard Wood data but are only required to provide enough to verify energy savings as part of the ESPC M&V requirement.
- **Government DDC** – Most buildings (Allen will provide a list) are set up with a LON based DDC system that could be interfaced to read meters. These systems are stand alone, with each building having its own LNS database.
- **Manual reading** Approximately 300-500 meters exist that are not advance meters. The readings are keyed into an access database.

Path forward

There are several possible paths forward. Integrating the disparate systems is a complex issue. It will take a significant of time to resolve the optimal path. The discussions during the site visit explored the following options:

- Integrate all meters into the Honeywell EBI front end
- Integrate all meters into the Fort Leonard Wood DDC systems
- Integrate all meter data into a Meter Management system such as Itron or MDMS

- Integrate into one master spreadsheet

They all have various advantages and disadvantages.

Option A

This will require patch cables for the Omega gas meters in order to get the pulse output to either a building controller or BPOC. Electrical meters will requires addition of a pulse output to smart electric meters (which will likely require removal of the smart module) and trenching from the transformer mounted meters to a building controller or BPOC, or installation of a new meter inside the building. Electric meters that are currently manually read will require either addition of pulse output ran to a controller or BPOC, or installation of a new meter with either LON communications or a pulse output connected to a controller or BPOC. It will also require systems integration on the EBI.

Advantages

- 32 electric and 14 gas meters are already read or soon will be
- Most easily integrated with Huntsville MDMS system

Disadvantages

- Relies on Honeywell
- Requires modification to ESPC contract
- Integration of the electric meters is problematic (trenching and smart module issue)

Option B

Integrating all meters into the Fort Leonard Wood DDC systems is very similar to Option A. Many of the issues involved with Option A would also have to be addressed in Option B. The main difference would be using a front end different from the Honeywell EBI. This may be appealing since it keeps metering separate from the ESPC contract.

Advantages

- Uses existing systems
- Does not require modification to ESPC contract

Disadvantages

- Smart electric meter pulse output and distance from building issue
- Because there is no master LON database and the installation wishes to keep it that way, integrating information could be problematic
- Integration of the electric meters is problematic (trenching and smart module issue)

Option C

Using a meter management system (MMS) may allow integration of the existing meter collection systems. It would require both software and hardware. Detailed discussions with a MMS vendor is required before the viability of this option can be adequately evaluated.

Advantages

- These systems were designed to solve some of the issues involved

Disadvantages

- Purchase of MMS required
- The cost of configuring the software is unknown and could be significant
- Requires coordination and cooperation with Omega and Laclede

Option D

This is a brute force option that would automate the process of consolidating the existing disparate metering data formats. It would be problematic to implement and likely would result in more data anomalies than the other options. It is the least elegant solution.

Advantages

- Relatively easy to use format

Disadvantages

- Requires development of custom software

- Future changes to upstream systems may require update of custom software

Huntsville MDMS system

The main focus of this trip was the integration of the various existing and planned metering systems at Fort Leonard Wood. An eventual goal is the integration of this data with a planned centralized metering system located at Huntsville. The need for this goal is questionable in this researcher's opinion, as it is for the utility representatives and Fort Leonard Wood. Building by building energy use data for the Army as a whole is of questionable use. This information is however of worth at the installation level as a tool for identifying problem buildings which may need repairs or upgrades to reduce energy use. It is my opinion that instead what should be reported to an Army centralized data base (or perhaps on a regional basis) is the entire installation energy use. This could be used for regional management of energy use such as negotiations of utility rates. At Fort Leonard Wood this would involve only four meters.

Wrap up/follow up (requires additional funding)

- Fort Leonard Wood and Huntsville need to decide to what extent they would like ERDC-CERL to be involved in metering plans and determine if there is funding available to support such efforts.
- Determine whether or not the smart electric meters can provide a pulse output without removing the AMI smart module.
- Compile a master list of meters sorted by current method of data collection and plan for integration.

Appendix D: Deconstructing WWII-Era Buildings at Fort Leonard Wood Missouri–A Feasibility Assessment

Background

ERDC-CERL personnel are supporting the Fort Leonard Wood (FLW) Directorate of Public Works (DPW) in their development of a Comprehensive Installation Strategic Sustainability Plan. Part of this Plan will consist of reducing solid waste, which includes waste generated by demolition and new construction projects – C&D waste.

The Army's policy is to remove World War II-era wood buildings from its real property inventory. Although the majority of wood buildings have been removed from Fort Leonard Wood, dozens still remain. Many of them are larger industrial-type buildings. The current practice at Fort Leonard Wood has been to mechanically demolish (wreck) the buildings, crush the debris haul it to a landfill in Arkansas.

The Department of Defense's Strategic Sustainability Performance Plan, which is observed by the Army, requires a minimum of 56% C&D materials be diverted from landfill disposal in Fiscal Year 2013, 58% in FY 2014, 60% in FY2015 and thereafter. Furthermore, in order to comply with the Army's Net Zero directives, specifically Net Zero Waste, waste from building demolition must be dramatically reduced. Fort Leonard Wood is exploring methods to reduce the waste generated by the removal of WWII-era buildings.

Deconstruction is one method for removing buildings, as is wrecking. Deconstruction involves disassembling buildings and recovering materials with the intent to reuse them to the greatest extent practical, recycle what is unsuitable for reuse, and dispose of the remaining materials in an appropriately licensed facility. Previous Army experience in deconstructing WWII-era wood buildings has been successful. Diversion rates of over 90% have been achieved.

Introduction

ERDC-CERL personnel surveyed three WWII-era wood buildings at Fort Leonard Wood in September 2012. These are Building 2352, Laundry; Building 2565, General Storage; and Building 2314, General Purpose Warehouse. The objective of this assessment was to determine whether deconstructing these buildings is or is not feasible. This survey includes two areas of evaluation. The first is the characterization of the buildings, which describes the building's construction type and materials, reuse potential for the materials, potential methods to remove the building, occurrence of damage or deterioration that would decrease the value of the materials, and other features that would facilitate or inhibit materials recovery. The second is assessing the availability of services to perform deconstruction, as well as potential reuse outlets for the materials once they are recovered from the buildings.

The building characterizations consisted of visual observations and measurements, upon which quantity take-offs were performed. The primary material of interest is lumber, and more attention was devoted to describing wood materials used in structural and enclosure applications. Also noted are other materials and components that may be recovered for reuse such as doors, windows, finish materials and mechanical and electrical items. Recyclable materials were also noted, consisting mostly of metals; pipe, conduit, copper conductor, etc. However, as recycling metals is standard practice during demolition, and will occur regardless of whether the buildings are demolished or deconstructed, only a cursory survey of these materials was made.

The primary purpose of the building descriptions provided below is to give Fort Leonard Wood DPW personnel an appreciation of the types and quantities of materials available in the buildings. These descriptions can also be used by potential deconstruction contractors and material outlets to help determine their interest in participating in these projects, if the decision is made to pursue a deconstruction approach. Thus, features of the buildings' construction (which may impact deconstruction) are also described to a level of detail useful to prospective contractors. Building 2352 was the only building identified for removal in FY2013. Removal of the others is planned sometime after FY2013. Each building was evaluated separately, as if it will be removed through a separate contract action. Therefore, common features and descriptions are repeated for each building.

Note that wood quantities shown below represent the major wood members that would be salvageable and reusable. Other miscellaneous wood such as blocking was not counted. For example, there are over 3,100 pieces of 2x8 and 2x6 blocking in the Laundry's roof and walls – each piece being 16-1/4" long. Reuse of these pieces may not be realistic, although they should be recyclable as mulch, erosion control or bio-fuel.

Ladders or lifts were not available for use to closely inspect elevated building features. Most observations were made from the ground. Some climbing on the building's structure and/or its contents enabled close observation up to about 20' in height. Otherwise, use of a telephoto lens and indirect measurements had to suffice. Any such errors resulting from inaccessibility should not be significant.

This feasibility assessment is an informal document presented to the Fort Leonard Wood DPW for their information. It has not been edited and is not an official ERDC-CERL Technical Report

Building 2352, Laundry

General

Building 2352 was an active laundry facility until December 2011. This building is now being used as a storage facility, and is scheduled for demolition in FY2013. It is approximately 270' x 214' in overall dimension and approximately 40,150 square feet in plan area.

Building 2352 west (left) and north (right) elevations.

Building 2352 south (left) and east (right) elevations.

The building consists of a high bay area of 162' x 216' laid out in structural grid of 18' x 18'. Columns are placed at 18' in each direction and support a clerestory, or "saw-tooth. " style roof. Windows are built into each vertical surface of the clerestories. Eave height is approximately 13'-6 at the low points and approximately 20' at the high points. An office/break area (38' x 91', 3,450 SF), maintenance area (18' x 56', 1,000 SF), and receiving area (16' x 43', 688 SF) are adjacent to the main high bay area. Eave height at these attached areas is approximately 10'. The roof covering is a membrane, assumed to be EPDM judging by its black color. The exterior of the building was originally built with wood sheathing and siding. Insulation board and steel siding has been added to the walls. Windows are aluminum replacement-style double-hung windows, personnel doors are hollow steel and overhead doors are steel. There is relatively little interior partitioning in the building.

A significant amount of laundry equipment, hot water piping and electrical distribution are present. The useable laundry equipment will most likely be removed, although many pieces of obsolete equipment and accessory items will likely remain in the building.

DPW personnel indicate that toxic materials that may have been used in dry cleaning were confined to an adjacent building and not stored in the laundry building itself. If there is any such contamination in the building structure, it would be confined to a very small area at the east end of the building, around vents for example. A survey will be conducted and if contamination is found, the area will be isolated from the remainder of the building and removed and disposed of separately.

Site

The jobsite is flat and not confined. The building is accessible from all four sides. There is ample area for materials processing on the south and east sides of the building. However, the old power plant stands at the southeast corner, restricting access between the areas to the south and east. There is vehicle access and working room on the north side of the building. Louisiana Avenue boarders the west sides of the building, although a parking apron should provide working area without intruding into traffic.

Foundation

The building's foundation is a concrete slab-on-grade of unknown depth. It is assumed piers and footings carry the columns. The foundation may possibly remain in place during the building's removal. A recessed loading dock is located on the west side of the building.

Structural systems

The high bay clerestory roof is supported by 6x6 columns placed on an 18' x 18' grid. They are approximately 13'-6 high. Each column is braced at the top with four- 6x6 diagonal braces approximately 5' long. Some of these braces appear to be replacement members and appear to be preservative treated. The columns are braced horizontally by two 2x10s perpendicular to the clerestories and four 2x10s parallel with the clerestories, on which the clerestories bear. The 2x10s are nominally 18' long. Virtually all connections are nailed. The structure is unpainted with the exception of some columns.

Diagonal bracing (left) and horizontal bracing (right) at columns.

The roof support system (columns and bracing) includes the following (quantities are rounded):

- 12,100 Board Feet (BF) of 6x6 columns & bracing
- 17,600 BF of 2x10 horizontal braces & beams

The roof structure consists of 2x8 rafters spaced at 18”. Rafters bear on the tops of the clerestories at the high end, and the horizontal beams between columns at the low end. The clear span is nominally 18’ although the members themselves are at least 19’ long. The roof deck consists of 6” boards running perpendicular to the rafters. The roof deck is likely to be tongue-and-groove (T&G), as T&G boards were found at the wall sheathing. At the south side of the high bay area the rafters bear on a bearing wall. The roof structure is unpainted.

Rafters bearing on a clerestory (left) and a bearing wall (right)

The roof structure itself consists of the following (quantities are rounded).

- 41,000 BF of 2x10 rafters
- 42,000 SF of 6" roof deck

Recovering the roof decking should not be assumed as a certainty. It is unknown whether the current membrane roofing is overlaying a former roof covering, or whether a tear-down was performed prior to installing the current roofing. Thus, what is adhered to the roof deck and how tenaciously it is adhered could not be determined by observation. Furthermore, in more southern latitudes, roof decking boards frequently become brittle after 70 years of exposure and may be unsuitable for reuse.

The clerestories are essentially 6' high walls that bear on horizontal beams between the columns. They are built with 2x6 studs, but the clerestory area is primarily windows. The rafters are carried by three 2x6 plates. There are double trim studs between window units and the remainder of the studs is cripples. There is also a 2x12 catwalk hung from the rafters to allow access to each row of clerestory windows. Catwalk boards are 18' long. The clerestory is unpainted, although there appears to be a considerable amount of dust and dirt around vent locations. The clerestory components consist of the following (quantities are rounded).

- 12,500 BF 2x6 wall studs
- 3,800 BF 2x12 catwalk

Water damage should be a concern in a roof such as this because of the difficulty in keeping long valleys sealed. Leakage was evident at the valleys and some of the lumber in this area was stained. However, there did not appear to be significant deterioration in these members. Personnel occupying the building report leakage in the past, although the most recent reroof is effective in preventing leaks. The vast majority of the lumber used in roof support and framing should remain serviceable for reuse.

Water stains under clerestory windows. Note 2x12 catwalk surface and framing.

If the majority of the framing lumber and sheathing board were recovered for reuse, roughly 200 tons of wood materials would be diverted from landfill disposal.

Exterior enclosure

As discussed above, the roof deck consists of 6” board, which is assumed to be T&G. This material may or may not be recoverable for reuse. The membrane roofing will become debris in all likelihood.

Exterior walls are framed with 2x6 studs spaced at 18”. Studs are 13’-6 high at the high bay area and 10’ high at the other areas of the building. 6x6 columns are built into the exterior walls at the column lines of the high bay area. There are two top plates at the top of the walls and a bottom plate at the bottom. At the south wall of the high bay area there is a 2x10 ledger running the length of the building to carry the rafters.

Walls are sheathed with 6” T&G board, applied diagonally in some areas and horizontally in others. The wall framing and sheathing (both sides) are unpainted. Applied to the board sheathing is 6” wood siding milled with a “Drop 105” profile. This is siding profile is typical of Army WWII mobilization construction. The siding is coated with what is undoubtedly lead-based paint.

The walls were originally not insulated. A foil faced ¾” polyisocynurate insulation board and 6” shiplap-style steel siding has been applied over the original wood siding. The insulation can be salvaged for reuse, although this may or may not actually be an attractive material. The steel siding can be removed for reuse. However, the care and effort to do so without damaging the panels may render this economically unfeasible and recycling may be the best that can be accomplished.

Exterior wall framing and sheathing (left, note 6x6 column and 2x8 ledger) and exterior steel siding.

The exterior wall components consist of the following (quantities are rounded).

- 9,800 BF of 2x6 wall studs & plates
- 660 BF of 6x6 columns
- 800 BF of 2x10 ledgers
- 8,600 SF of 1x6 T&G board sheathing
- 8,600 SF of 6” T&G exterior sheathing

- 8,600 SF of ¾” foil faced polyisocynurate insulation board
- 8,600 SF of 8” steel siding (or roughly 8.6 tons at 2 lbs/SF)

If the majority of exterior wall framing and sheathing were to be reused, roughly 15 tons of lumber would be diverted from landfill disposal.
The eaves and rakes at the gable ends are finished with aluminum soffit and fascia material, which will be available for recycling. There are approximately 5,500 square feet of soffit and fascia, which represents roughly 2,300 lbs. of aluminum scrap.


Aluminum soffit and fascia at loading dock (left) and at clerestories (right).

The current windows are aluminum double-hung replacement style windows with combination storm/screen assemblies. These should be easily removable for reuse. Some screens are missing, although the vast majority of windows appear serviceable. While not high performance windows , they would be suitable for garages, sheds and other buildings where heating and cooling are not major issues.


Aluminum windows at ground level (left) and in the clerestory (right).

The inventory of windows in Building 2352 is as follows (note dimensions are finish dimensions, not rough opening dimensions):

- 75 - 7-‘0 x 3’-4
- 8 - 4’-6 x 2’-6
- 55 - 3’-6 x 4’-0

There are seven personnel doors and two overhead doors. Of the personnel doors, three are of such condition they would not be attractive for reuse.

Potentially reusable personnel doors (left) and overhead doors (right).

Doors with reuse potential are as follows (note dimensions are finish dimensions, not rough opening dimensions):

- 1 - 5’-0 wide x 6’-7 high double door with vision panel in each leaf.
- 3 – 5’-0 wide x 9’-0 high double doors
- 2 – 8’-0 x 8’-0 overhead sectional doors

Interior construction

There is minimal interior partitioning in this building. Within the high bay area partitions are constructed with 2x6 studs and 1x6 T&G board finish on one side. The majority of the wall surface has been painted on at least one side. These partitions are 13’-6 high. Within the office/break area, the partitions are constructed with 2x4 studs and gypsum wall board finish on both sides. These partitions extend to the bottom of the roof frame, which slopes from 13’-6 to 10’-0.

The interior wall components consist of the following (quantities are rounded).

- 3,400 BF of 2x6 wall studs
- 3,200 BF of 2x4 wall studs
- 6,000 SF of 6” T&G board wall finish
- 4,700 SF of GWB (which will become debris)

Approximately 1,700 SF of suspended acoustical ceiling is installed in the office area. Ceiling tiles are recyclable through Armstrong World Industries. However, working with Armstrong’s collection system may be impractical given the relatively small quantity available.

There is a steel frame installed in the high bay area fabricated from wide flange shapes. This will likely remain in the building and will available for recycling. A take-off was not completed on this frame.
Wood laundry bins were constructed in the high bay area, along and anchored to the east wall. Each bin is 5’ wide and approximately 13’-6 high. Framing consist of 2x4, 2x6 and 4x4 members. Framing members are 5’ to 10’ and more in length. The bins are enclosed by 1x3 slats. Slats range from a few inches to 13 feet long. Horizontal framing members (10’ and longer) ought to be recoverable for reuse. The vertical framing members (5’) may not be of sufficient length to be attractive for reuse. While there is a significant quantity of 1x3 slats, their potential for reuse may be questionable.

The laundry bins consist of the following (quantities are rounded).

- 250 BF of 2x6s
- 850 BF of 2x4s
- 170 BF of 4x4s
- 2,400 BF of 1x3 slats

Steel frame (left) and wood laundry bins (right) in the building's interior.

Plumbing

There are 15 toilet and lavatory fixtures in the laundry building. Some appear to be original and some are replacements. Lavatories are of both ceramic and cast iron materials. There is one stainless steel double utility sink. With the exception of the stainless steel sink, none of these fixtures would be attractive for reuse, so no further description is given here.

Considering only the piping required for these fixtures, there would be roughly 200' of 1" diameter steel supply pipe and 150' of 6" diameter cast iron drain-waste-vent (DWV) pipe. Altogether this would be roughly 1,000 lbs of metal piping, or roughly 0.5 tons. Note that the building supply and branch piping and building DWV is not included in this estimate.

Mechanical systems

Only a cursory count of mechanical components was made, as metals will be recycled regardless of whether the building is removed by wrecking or deconstruction.

This building includes a sprinkler system and hot water heating distribution for laundry process equipment and hot water heaters in the following quantities (which are rounded).

- Roughly 7,500' of 10", 6" and 2" sprinkler pipe (over 25 tons)
- Roughly 12,500' of 3", 2"and 1" hot water pipe (roughly 21 tons)
- 13 ceiling hung hot water heaters

Significant quantities of miscellaneous hot water lines are also present throughout the building that is not included in this estimate. This pipe is insulated, and the insulation material was reported to not be asbestos.

One of the original large compressors remains in the building; the weight is undetermined but should be at least several tons of scrap iron. Additional process equipment will also remain in the building, although it is not determined exactly what will be removed and what will remain.

Hot water distribution lines.

Electrical systems

Only a cursory survey of electrical components was made, as copper conductor and metals will be recycled regardless of whether the building is removed by wrecking or deconstruction. The majority of the light fixtures should be reusable in utilitarian applications. The building includes the following electrical components.

- 240-4’ 2-tube fluorescent ceiling-hung industrial type light fixtures
- 12-2’x4’ 2-tube fluorescent lay-in fixtures
- 24-2’x2’ lay-in fluorescent fixtures
- At least 2,000 pounds of recyclable copper conductor.
- At least 22 tons of recyclable metals from conduit and raceways.
- Other miscellaneous recyclables; main switches, load centers, circuit breaker boxes, etc


Light fixtures and electrical raceway (left) and electrical conduit (right).

Miscellaneous electrical components.

Conclusions

Building 2352, Laundry, is an excellent candidate for deconstruction. No conditions or construction features were observed that would suggest deconstruction would be especially difficult. Wood framing and sheathing boards are the primary materials of interest for recovery and reuse, although there is a significant amount of metal components that should be recycled as well. The building employs conventional wood framing and construction techniques, which lend themselves to disassembly. Roughly 150,000 BF of lumber materials (over 200 tons) would be available for recovery and reuse. Specific issues are as follows.

- While roof leakage was evident at the clerestories, there was no significant damage or deterioration observed. While some deterioration must be expected in wood buildings this old, it appears the vast majority of wood materials should still be sound and recoverable for reuse.
- The scale of this building would preclude smaller, “mom-and-pop” contractors from participating in this project, at least as a prime contractor. Knowledge of structure, capabilities with lifting equipment, construction aids, materials management and overall construction management skills would need to be present. However, smaller or specialty contractors could successfully participate under the umbrella of a qualified General Contractor.

- The structural system is laid out as a grid and disassembly can progress on a bay-by-bay basis, each bay independently without destabilizing adjacent bays. Member dimensions are such that handling should present no extraordinary difficulties.
- The wood species is most likely a Southern Pine, although this is yet to be confirmed.
- As this was constructed as a utilitarian building, there is relatively little finish material that must be removed to access the lumber. Finish materials will likely be disposed of as debris.
- The presence of obsolete equipment and networks of process piping and electrical service present both an opportunity and a major task. There are at least 60 tons of recyclable metals in the building; more in all likelihood. However, these materials must be removed prior to disassembly to allow access to the building's structural components.
- The presence of toxic dry cleaning chemicals may be a concern, although it was reported any contamination would be very limited in area, if present at all. Prior to demolition or deconstruction activities the building would have to be surveyed and contaminated material would have to be removed and disposed of separately.
- Pipe insulation was reported to not be asbestos. Aside from the inconvenience of removing it, there should be no hazard associated with the piping materials. No other asbestos was reported in this building. However, an asbestos survey would have to verify the absence of asbestos from this building.
- Removing fluorescent lamps, mercury (Hg) switches, PCB containing ballasts, and other hazardous building materials will need to take place regardless of whether the building is wrecked or deconstructed. This should not affect a deconstruction approach.
- The original exterior siding and interior paints are certain to be lead-based. As the condition of the exterior materials was not observable, the reuse potential is uncertain. While there is no federal level regulation that would prevent the transfer and resale of lead-base painted material, it may be prudent to dispose of the siding as debris, unless it is found to be a high grade material in excellent condition.

Building 2565, General Storage

General

Building 2565 is a general purpose storage building. It is approximately 76' x 240' in overall dimension and approximately 18,200 square feet in plan area.

Building 2565 west (left) and north (right) elevations.

Building 2565 south (left) and east (right) elevations, respectively.

The building is a simple rectangular building consisting of a single clear span high bay area. Trusses span the 76’ width and are carried by columns built into the exterior walls. The roof is a low slope configuration, the slope achieved by the top chords of the trusses. Eave height is approximately 21’ at the low points and ridge height is approximately 22’. A small office and storage area (20’ x 25’, 500 SF), was constructed within the high bay area. The roof covering is a metal roof. The exterior of the building was originally built with gypsum wall board (GWB) sheathing and wood siding. Insulation board and steel siding has been added to the walls. Windows are steel framed (assumed original) and aluminum framed storm window panels have been added. Personnel doors are hollow steel and overhead doors are steel. There is relatively little interior partitioning in the building.

Site

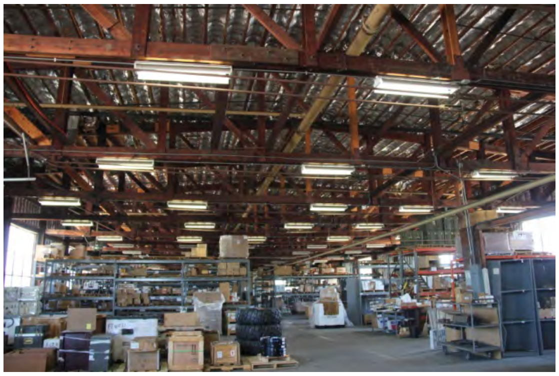
The jobsite is somewhat confined by an Ordinance Road to the south, a grade difference and loading dock to the west and a railroad track to the north. However, there is ample area for materials processing on the east side of the building. Working room on the south side of the building will be restricted by Ordinance Road. Vehicle access and some working room exist on the north side. The loading dock on the west side will allow some working room as well.

Foundation

The building's foundation is a concrete slab-on-grade of unknown depth. It is assumed piers and footings support columns. This foundation may possibly remain in place during the building's removal.

Structural systems

The primary structural members are trusses spanning the building's width. Trusses are spaced at 15'. They are approximately 6' deep at the ridge and slope to approximately 5' deep at the eaves. They are fabricated from 2x8, 3x8, 3x10 and 3x12 members. Connections are bolted. Chord members are approximately 10' to 15' long and web members are approximately 6' long. Lateral bracing between trusses is achieved by 4x12 timbers. Steel tie rods are placed at the bottom chords to carry tension forces. Steel plates anchor the tie rods at the building's exterior walls and the trusses are carried by reinforced steel plates. Trusses are carried by columns built into the exterior walls. These columns are fabricated from three 3x14 timbers, 20' tall. Connections are bolted. The structure has not been painted.



Truss clear span (left) and detail (right).


Truss bearing on columns at exterior wall (left) and midspan detail (right).


Tie rod anchors at the building's exterior walls (left)
and truss carrier plates (right).

The primary structural system includes the following (quantities are rounded):

- 6,300 BF of 3x14 columns
- 2,100 BF of 2x8 truss web members
- 2,800 BF of 3x8 truss chord members
- 2,800 BF of 3x10 truss chord members
- 3,400 BF of 3x12 truss chord members

- 2,300 BF 4x12 lateral bracing
- 5 tons of tie rods and anchor plates and brackets

The roof structure consists of 2x8 rafters deployed purlin-style, perpendicular to the trusses and running the long direction of the building. Rafters are spaced at 16”. The rafter span is nominally 15’ although the members themselves lap over the trusses and are closer to 18’ long. The roof deck consists of 8” boards running perpendicular to the rafters. The roof deck is likely to be tongue-and-groove (T&G), as T&G boards were found in other Fort Leonard Wood WWII-era buildings. There has been a significant amount of roof repair and reconstruction. Plywood roof deck and new rafters replace the original construction at an estimated 20% of the roof area. In most places, new rafters are sistered onto the existing rafters.

Roof frame and deck repair/replacement
(Note: multiple new rafters “sistered” into existing rafters).

The roof structure itself consists of the following (quantities are rounded)

- 20,000 BF of 2x10 rafters (including additional sistered rafters)
- 14,500 SF of 8” T&G roof deck
- Approximately 3,600 SF of plywood roof deck (thickness is unknown; assuming 1/2”)

Recovering the roof decking should not be assumed as a certainty. It is unknown whether the current metal roofing is overlaying an older roof covering, or whether a tear-down was performed prior to installing the current roofing. If an existing built up roof covering is still in-place, removal from a wood deck may be problematic. That said, no bitumen drips between roof deck boards were observed. If a cap sheet is in place between the deck and bitumen roofing, that should make removing the roof covering easier. Furthermore, in more southern latitudes, roof decking boards frequently become brittle after 70 years of exposure and may be unsuitable for reuse.

Water damage has obviously occurred in this building, which is predictable given its low slope roof. However, extensive repairs are evident. Water leakage is evident at the ends of the trusses and tops of columns, where the roof and/or wall apparently leaked. Water leakage is also evident at window sills. However, there did not appear to be significant deterioration in the existing or newer members. The majority of the lumber used in roof support and framing should remain serviceable for reuse.

A caveat: Neither the walls nor the roof were originally insulated. Foil faced fiberglass bat insulation has been installed between rafters and between studs. The presence of this insulation makes it difficult to assess the condition of the framing members and sheathing in all locations. The gypsum wall board sheathing (GWB) is deteriorated in several places, especially at window sills and at the columns. However, by peeling away insulation in random locations, it appears the wall and roof framing materials are generally still sound.

If the majority of the framing lumber and sheathing board were recovered for reuse, roughly 70 tons of wood materials would be diverted from landfill disposal.

Exterior enclosure

As discussed above, the roof deck consists of 8” board, which is assumed to be T&G. This material may or may not be recoverable for reuse. The roof covering was reported to be a metal roof system, which should be recycled. If there is another roof covering below the metal roof, it will become debris. Note, however, that the Google satellite image of this building suggests a built-up or an elastomeric membrane roof covering. Although a fixed ladder was available for roof access, no fall protection was available and therefore the ladder could not be used, and the roofing could not be observed first hand. For the purposes of this evaluation, it is assumed the roof covering is metal, as reported.

Exterior walls are framed with 2x4 studs spaced at 16”. The full height studs (not cripples at windows) are 21’ long. It appears as though several original window openings have been famed in and covered. These studs are approximately 10' long. Columns fabricated of three 3x14 timbers are built into the exterior walls to carry the roof trusses. One 4x6 timber runs horizontally at the tops of the exterior walls. There is a 2x8 ledger or brace nailed to the interior edge of the wall studs between the eave and the window header. Two 2x8s and one 4x6 timber are installed horizontally at the window heads to carry vertical loads over the windows. Two 2x8s and one 3x8 run horizontally at the window sills.

Exterior wall framing details, note column (left) and window header detail (right.
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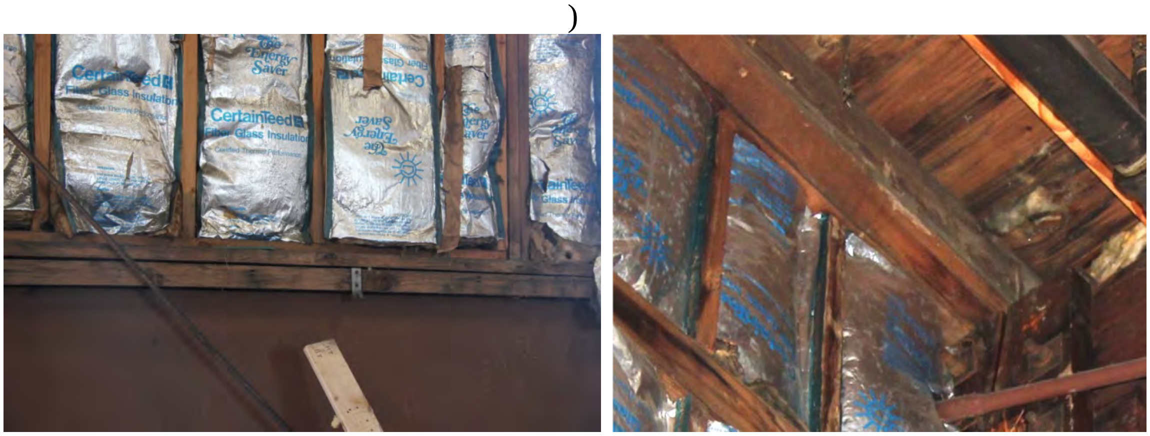


Exterior wall framing details, note window sill framing (left) and beam at eave (right).

Exterior siding.

Exterior walls are sheathed with gypsum wall board (GWB), which will become debris. The wall framing and sheathing (both sides) are unpainted. The walls were originally not insulated. Foil faced fiberglass bat insulation has been installed between studs. Applied to the GWB sheathing is 6" wood siding milled with a "Drop 105" profile. This is siding profile is typical of Army WWII mobilization construction. The siding is coated with what is undoubtedly lead-based paint. A foil faced ¾" polyisocynurate insulation board and 8" steel siding has been applied over the original wood siding. There is no roof overhang and therefore no fascia and soffit.

The exterior wall components consist of the following (quantities are rounded).

- 2,700 BF of 2x4 wall studs & plates
- 1,200BF of 4x8s
- 1,000 BF of 4x6s
- 1,000 BF of 3x8s
- 5,100 BF of 2x8s
- 11,600 SF of 3-1/2" foil faced fiberglass bat insulation
- 11,1600 SF GWB exterior sheathing
- 11,100 SF of wood exterior siding
- 11,600 SF of ¾" foil faced polyisocynurate insulation board
- 11,600 SF of 8" steel siding (or roughly 11 tons at 2 lbs/SF)
- 18,240 SF of metal roofing (or roughly 12 tons at 1.4 lbs/SF)

The insulation boards can be salvaged for reuse, although this may or may not actually be an attractive material. The steel siding can be removed for reuse. However, the care and effort to do so without damaging the panels may render this economically unfeasible and recycling may be the best that can be accomplished.

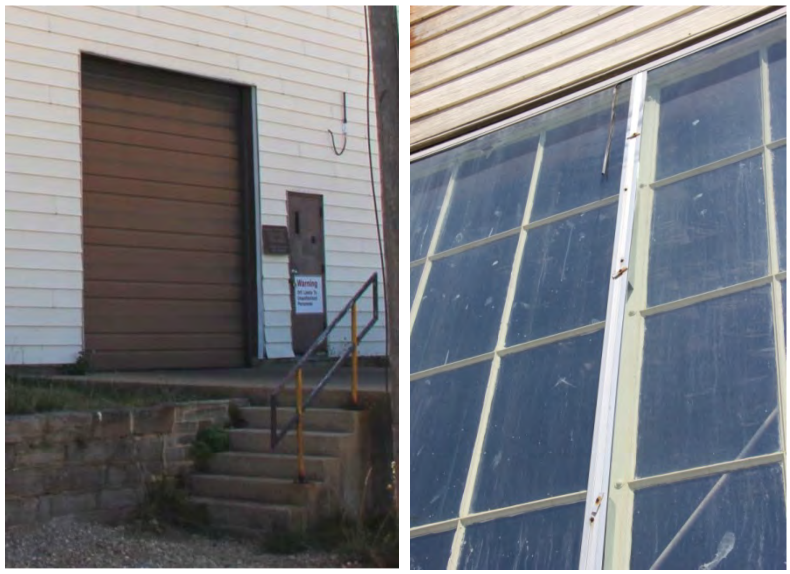
The presence of the fiberglass batt insulation makes it difficult to assess the condition of the framing members and sheathing. Water staining is evident at window sills and at the ends of the trusses where they interface with exterior walls. The GWB is deteriorated in several places, especially at window sills and at the columns. However, by peeling away insulation in random locations, it appears the wall and roof framing materials are generally still sound.

One area at the west end of the south wall has suffered significant damage, apparently from water leakage, and is buckling outward. It is shored at the outside, extensive repairs have been made at the roof and an additional column columns supports the roof at the interior. The damage has been repaired and the building is still occupied and stable. However, this condition will have to be addressed in the structural survey developed prior to either wrecking or deconstruction to ensure unintended collapse is avoided.

Shoring at the south wall.

There are 3 exterior hollow metal personnel door, a double door at the boiler room and 3 overhead doors. The double door is damaged and one overhead door was reported to not be working properly. The other doors are operable, although none would be especially attractive for reuse with the possible exception of a relatively new overhead door. Unusable doors should be recycled.

The windows appear to be original steel framed multi-lite windows. They have been covered with aluminum framed exterior storm window panels. None of these windows would have much reuse potential. The frames should be recycled.



Overhead and personnel doors (left) and window detail (right).

An inventory of exterior doors and windows is as follows.

- 3 – 3’ wide x 6’-7 high hollow metal personnel doors
- 1 – 3’ wide x 6’-7 high double hollow metal personnel door at the boiler room)
- 3 – 10’ wide x 12’ high steel sectional overhead doors
- 10 – 10’ high x 13’ wide steel framed fixed windows w/ aluminum framed storm panels.

Interior construction

A small office and storage area is constructed in at the southwest corner of the building. This area also separates the former boiler room from the building’s interior. Partitions are framed with 2x4s onto which 6” T&G board has been applied to one side. The interior of the boiler room is finished in GWB. The partitions extend to the bottom of the roof deck, approximately 21’ high. These partitions have been painted.

Interior construction consist of the following (quantities are rounded)

- 1,300 BF of 2x4 studs
- 4,700 SF of 6” T&G board
- 2,600 SF of GWB

Plumbing

There are 14 toilet, urinal trough and lavatory fixtures in the laundry building. Most appear to be original. None of these fixtures would be attractive for reuse, so no further description is given here.

Considering only the piping required for these fixtures, there would be roughly 160’ of 1” diameter steel supply pipe and 100’ of 6” diameter cast iron drain-waste-vent (DWV) pipe. Altogether this would be roughly 500 lbs of metal piping, or roughly 0.25 tons. Note that the building supply and branch piping and building DWV is not included in this estimate.

Mechanical systems

Only a cursory count of mechanical components was made, as metals will be recycled regardless of whether the building is removed by wrecking or deconstruction.

This building includes a sprinkler system, hot water heating distribution and ceiling hung hot water heaters. The original boiler remains.

The sprinkler system consists of a 6” diameter main, 8” diameter risers, 3” sub main and 2” diameter piping. There are roughly 200’ of sprinkler main and roughly 480’ of sprinkler distribution piping. Altogether there is in excess 10 tons of sprinkler pipe in the building available for recycling.

Hot water piping runs the length of the building to supply ceiling-hung hot water heaters. Altogether there is roughly 800’ of 6”, 3” and 2” steel hot water pipe, or over 10 tons of pipe available for recycling. This pipe is insulated, and the insulation material was reported to not be asbestos.

Mechanical components consist of the following (quantities are rounded):

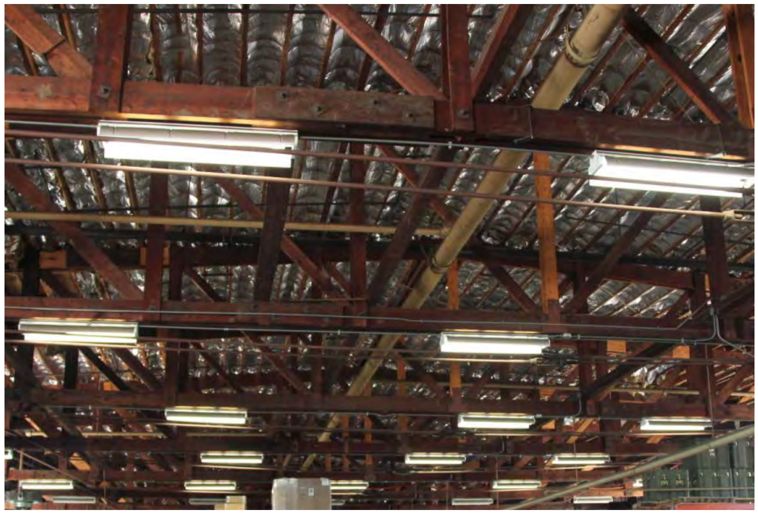
- Roughly 200’ of 3”, 6” and 8” of sprinkler pipe (over 10 tons)
- Roughly 800’ of 2”, 3” and 6” hot water pipe (roughly 10 tons)
- 13 ceiling hung hot water heaters
- 1 cast iron boiler (roughly 10 tons)

Hot water pipe hung from the roof (left)
and ceiling hung hot water heater (right).

Electrical systems

Only a cursory survey of electrical components was made, as copper conductor and metals will be recycled regardless of whether the building is removed by wrecking or deconstruction. The majority of the light fixtures should be reusable in utilitarian applications. The building includes the following electrical components.

- 75-4’ 2-tube fluorescent ceiling-hung industrial type light fixtures
- At least 100 pounds of recyclable copper conductor.
- At least 1.5 tons of recyclable conduit
- Other miscellaneous recyclables; main switches, load centers, circuit breaker boxes, etc



Ceiling hung fluorescent light fixtures.

Conclusions

Building 2565 General Storage, is a good candidate for deconstruction or at least partial deconstruction, given some reservations discussed below. Wood framing and sheathing boards are the primary materials of interest. The building employs conventional wood framing and construction techniques, which lend themselves to disassembly. Unlike other WWII-era buildings, this building contains heavier wood members than typical dimensional (2”) lumber. 3” and 4” wide members are present in quantity. These are classified as timbers, although it must be acknowledged they are not heavy timbers. Roughly 68,000 BF of lumber materials (over 200 tons) would be available for recovery and reuse. Specific issues are as follows.

- Leakage was evident throughout the building. Major repairs and replacement have taken place. One location is reinforced with exterior shoring and additional support at the interior. These repaired areas appear to be stable and can provide useable lumber and plywood. However, caution must be exercised when planning deconstruction to protect workers from hazard of unintended collapse. These precautions are equally applicable to wrecking as well.
- The timber members in the roof trusses and columns should be desirable for reuse. The length of most truss members is sufficient for reuse. Only the web members are shorter than is typically desired, although they may be used for millwork or other value-added products. The 2x4 wall and partition framing may not be attractive for reuse. A contractor

may find a partial deconstruction approach may be the most feasible, applying additional resources to the truss and column members but not the walls or partitions.

- The condition of the roof covering was not able to be observed during this survey. How the roof covering is removed will have a major impact on recovering the rafters and trusses. If an old “tar-and-gravel” or built up roof is in place, removing it from the roof deck will be time consuming and therefore expensive.
- Where leakage is evident, wood is stained. However there was no significant damage or deterioration observed. While some deterioration must be expected in wood buildings this old, it appears the majority of wood materials should be recoverable for reuse.
- The scale of this building would preclude smaller, “mom-and-pop” contractors from participating in this project, at least as a prime contractor. Handling the trusses would be the primary concern. Knowledge of structure, capabilities with lifting equipment, construction aids, materials management and overall construction management skills would need to be present. Of particular concern would be handling the trusses; either dismantling them at elevation or lowering them to the ground for disassembly. Smaller or specialty contractors, however, could successfully participate under the umbrella of a qualified General Contractor.
- The wood species is most likely a Southern Pine, although this is yet to be confirmed.
- There is little in the way of finishes, plumbing, mechanical or electrical components to interfere with extracting the desirable wood components. There are over 40 tons of recyclable metal roofing, siding, piping and conduit, although these should be removable easily enough.
- Pipe insulation was reported to not be asbestos. Aside from the inconvenience of removing it, there should be no hazard associated with the piping materials. No other asbestos was reported in this building. However, an asbestos survey would have to verify the presence or absence of asbestos from this building.
- Removing fluorescent lamps, mercury (Hg) switches, PCB containing ballasts, and other hazardous building materials will need to take place regardless of whether the building is wrecked or deconstructed.
- The original exterior siding and interior paints are certain to be lead-based. As the condition of the siding material was not observable, the reuse potential is uncertain. While there is no federal level regulation that would prevent the transfer and resale of lead-base painted materi-

al, it may be prudent to dispose of the siding as debris, unless it is found to be a high grade material in excellent condition.

- Including additional WWII-era wood buildings within the scope of one contract should greatly enhance the attractiveness of deconstructing Building 2565.

BUILDING 2314 GENERAL PURPOSE WAREHOUSE

General

Building 2314, General Purpose Warehouse, is an active materiel distribution facility. The building is 60' wide and 154' long and 9,240 square feet in plan area. The typical configuration at Fort Leonard Wood is two warehouses are built end-to-end. A brick fire wall separates the individual warehouses.

Building 2314 east elevation at the south end (left) and north end (right).

Building 2314 southwest corner (left) and west elevation (right).

This building type is common on Army installations and several have been successfully deconstructed. The foundation consists of five continuous footings and walls running longitudinally the length of the building. The ends of the foundation are closed by concrete footings and walls. The structure consists of a 10’ x 12’ structural grid and was originally built as an open storage building. Building 2314 retains approximately 7,200 SF of open warehouse and now has approximately 2,040 SF of office area. The floor is built over a crawl space with floor joists running laterally between foundation walls. Columns also bear on the foundation walls. Columns support beams which run longitudinally down the building’s length, which in turn support rafters. The roof is a simple gable roof with a pitch of approximately 4:12. Eave height is 10’ above the floor, although the floor is elevated an additional 3’-6 above grade by the foundation walls. The roof covering is three tab asphalt shingle roofing. The exterior of the building was originally built with wood sheathing and siding. Insulation board and steel siding has been added to the walls. Windows are aluminum replacement-style double-hung windows, personnel doors are hollow steel and overhead doors are steel.

Interior photographs of Building 2314 were not allowed during this survey. Another GP Warehouse building in the 2300 Block of Fort Leonard Wood was visited, and some of those photographs are included to represent Building 2314.

Site

The jobsite is flat but working room will not be unlimited. The site is defined by Quartermaster Street to the east and railroad tracks to the west, although some working room is available between the building and these features. Unless the adjacent building to the north is removed at the same time as building 2314, the firewall at 2314’s north end will be the jobsite boundary. There is an open area to the south that may be useable as a material processing area. However, there is a propane tank around which activities will have to be performed. Note that similar site conditions also existed when other similar warehouse buildings were deconstructed and proved to be no real obstacle. Most of the deconstruction work can take place within the building’s footprint.

Foundation

The foundation consists of five continuous concrete footings of an undetermined size and 8” thick walls running the length of the building. The size of the footings was not determined, although it is assumed they would be roughly 12” thick and 16” wide. The bottoms of the footings are assumed to be at frost line (approximately 20” below grade). The ends of the foundation are closed by concrete footings and walls. Whether removing the foundation is within the scope a deconstruction contract is yet to be determined.

Structural systems

The floor system consists of 2x12 joists spaced at 12” spanning between the foundation walls. The span is 12’ although with the overlap the members themselves are closer to 14’ long. Joists bear on 2x6 sill plates and 2x12 band joists run the length of the building at the exterior walls. The floor structure is unpainted. The floor deck was observable only from the crawlspace. Previous deconstruction experience indicates this is typically a 2x6 T&G board (“cardecking”), and is sometimes installed in two layers. In previous deconstruction projects, the floor supported light construction equipment (scissor lifts, skid-steer, etc) which expedited the deconstruction process.

GP Warehouse floor framing during deconstruction at Fort Campbell (left) and floor deck during deconstruction at Fort Carson CO (right).

The floor system includes the following (quantities are rounded):

- 900 BF of 2x6 sill plates
- 19,200 BF of 2x12 floor framing
- 18,400 BF of 2x6 T&G floor deck, assuming only one layer

The roof is supported by 6x6 columns placed on a 10’ x 12’ grid. Columns are 14’ tall at the outside rows and 17’ tall at the inner rows. Columns are braced in both the lateral and longitudinal directions by 2x6s, each member being approximately 12' long.

The roof support system (columns and bracing) includes the following (quantities are rounded):

- 1,500 Board Feet (BF) of 6x6 columns
- 3,300 BF of 2x6 horizontal bracing

Columns carry double 2x12 beams at each row, the length of the building. Rafters are 2x8s, spaced at 24", spanning between the ridge and exterior wall and bearing on the beams. Rafter members are nominally 18' and 12' long although lapping over the outer beam the 2x8s are at least 19' and 13' long. Roof decking is 8" board installed perpendicular to the rafters. Unlike other GP Warehouses, the roof support connections are nailed, not bolted. The roof structure is unpainted.

GP Warehouse columns and lateral support (left) and beams and rafters (right) at Fort Leonard Wood, MO.

The roof framing system (beams and rafters) includes the following (quantities are rounded):

- 2,400 BF of double 2x12 beams
- 5,000 BF of 2x8 rafters
- 9,500 SF of 1x8 roof decking

If the majority of the building's structural systems were recovered for reuse, roughly 40,000 BF (roughly 55 tons) of lumber would be diverted from landfill disposal.

Exterior enclosure

As discussed above, the roof deck consists of 6” board, which is assumed to be T&G. This material may or may not be recoverable for reuse. There is currently 7-1/2” Kraft-paper faced fiberglass batt insulation installed between rafters.

The roof covering is asphalt 3 tab shingle roofing. It appears there is only one layer of shingle, although this would have to be verified by peeling back the roofing. Asphalt shingles can be recycled into hot mix asphalt pavement, and at least one paving contractor in St. Robert MO accepts tear-off shingles for recycling. Recycling shingles will divert roughly 12 tons of debris from landfilling.

Exterior walls are framed with 2x6 studs spaced at 24”. Studs are 10’ high at the exterior walls. There are two top plates at the top of the walls and a bottom plate at the bottom. There is a 2x6 “toe plate” installed at the bottom of the wall around the perimeter of the exterior walls .

Walls are sheathed with 6” T&G board, applied horizontally. The wall framing and sheathing (both sides) are unpainted. Applied to the board sheathing is 6” wood siding milled with a “Drop 105” profile. This is siding profile is typical of Army WWII mobilization construction. The siding is coated with what is undoubtedly lead-based paint.

The walls were originally not insulated. A foil faced ¾ ” polyisocynurate insulation board and 8” shiplap-style steel siding has been applied over the original wood siding. There is also 5-1/2” fiberglass Kraft paper faced insulation between wall studs at the building’s interior. The insulation can be salvaged for reuse, although this may or may not actually be an attractive material. The steel siding can be removed for reuse. However, the care and effort to do so without damaging the panels may render this economically unfeasible and recycling is the best that can be accomplished. At the foundation, there are 5 fixed aluminum louvers 42” wide and 22” high. In the gable is one operable aluminum louver approximately 42” square.

The insulation at the building’s interior prevented a thorough examination of the framing and enclosure materials. However, spot checks indicated there was little if any water leakage into the interior and the materials that could be observed were in sound condition.

GP Warehouse exterior wall panel framing detail during deconstruction at Fort Gordon, GA (note exterior sheathing is GWB in this example).

The exterior wall components consist of the following (quantities are rounded).

- 3,500 BF of 2x6 wall studs & plates
- 3,400 SF of 1x6 T&G board sheathing
- 3,400 SF of 6” T&G exterior sheathing
- 3,400 SF of ¾” foil faced polyisocynurate insulation board
- 3,400 SF of 5-1/2” Kraft paper faced fiberglass batt insulation
- 3,400 SF of 8” steel siding (or roughly 3.4 tons at 2 lbs/SF)
- 5 – 42” x 22” aluminum fixed louvers
- 1 – 42” x 42” aluminum operable louver

If the majority of exterior wall framing and sheathing were to be reused, roughly 14 tons of lumber would be diverted from landfill disposal.

The eaves and rakes at the gable ends are finished with aluminum soffit and fascia material, which will be available for recycling. There are approximately 1,100 square feet of soffit and fascia, plus approximately 300 square feet of aluminum “paneling” covering the top and ends of the brick fire wall. Altogether this is roughly 700 lbs. of aluminum scrap available for recycling.

Aluminum soffit, gutters and exterior cover panels.

The current windows are aluminum double-hung replacement style windows with combination storm/screen assemblies, which are similar to other WWII-era buildings' replacement windows. These should be easily removable for reuse. While not high performance windows , they would be suitable for garages, sheds and other buildings where heating and cooling are not major issues. There are three 3' wide by 6'-7 high hollow metal personnel doors and two 8'x8' steel sectional overhead doors. These doors are serviceable and not damaged to any great extent. One overhead door was reported to be very recently installed.

Aluminum windows (left) steel overhead door (right).

Interior construction

Some partitioning has been added to create an office and break area at the south end of the building. Partitions are framed with 2x4 wall studs spaced at 24" and are 10' high. Wall surfaces are GWB. The interior surfaces of the office and break areas are finished with GWB. On the break area's south wall, which is the building's exterior wall, there is GWB wall finish that appears to have been installed over the original 6" board wall finish. There are two small restrooms and a utility room which are finished with 6" board. There is no interior finish on the east and west exterior walls. The north wall is the brick fire wall.

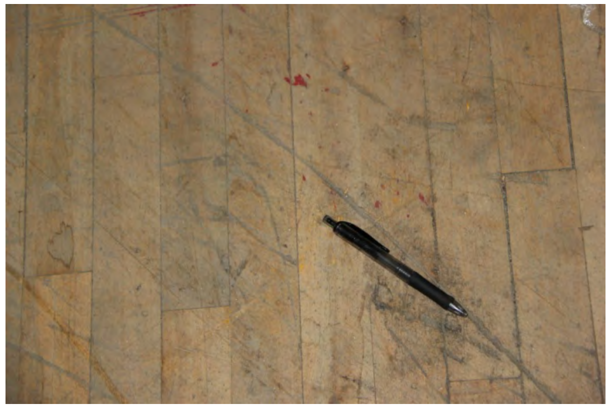
The floor finish is 2" strip maple floor, with the strips laid diagonally across the floor deck. This should be very attractive in the reuse market. While the finish is scuffed and dirty in places, it should be able to be refinished. An antique patina is desirable with recovered wood flooring

A suspended acoustical ceiling finishes the office area, which is approximately 360 square feet. A hard board (i.e. "Masonite") ceiling surface has been installed at the office/ break area, which is approximately 2,700 in area.

There is one wood framed interior window, 8' wide x 4' high, with three sliding glass panels. There are 3 -36" wide hollow core wood interior doors and three 24" wide wood doors at the restrooms.

There are two cubicles formed by office landscape partition systems, totaling 50 linear feet. It is yet unknown whether these will remain when the building is removed or not.

Ceiling tiles are recyclable through Armstrong World Industries. However, working with Armstrong's collection system may be impractical given the relatively small quantity available. While the interior doors and window are serviceable and can be reused, it is doubtful recovering them will be worth the effort for this small a number of items. If, however, multiple buildings are included in a building removal project, the combined interior items may be more attractive for recovery and reuse. At the very least, however, wood materials should be recycled.



Maple finished flooring at Fort Leonard Wood.

The interior components consist of the following (quantities are rounded).

- 1,800 BF of 2x4 wall studs and plates
- Up to 1,300 SF of 6” T&G board wall finish (most of it covered by GWB)
- 9,200 SF of 2” T&G strip maple flooring
- Roughly 2,000 SF of GWB (which will become debris)
- 360 SF acoustical tile ceiling
- 2,700 SF of Masonite ceiling surface
- 1- interior window, wood framed, 8’ x 4’

Plumbing

There is a minimal amount of plumbing in Building 2314 and therefore only a cursory survey was performed.

There are 2 – 2-fixture washrooms and a utility room with a 20-gallon residential style water heater. There is also a cold water fountain. The fixtures are old but not of a vintage character. They will probably not have any reuse attraction. Altogether there is roughly 500 lbs of steel water pipe and cast iron DWV available for recycling.

The water heater is of an unknown age, which would also make it unattractive for reuse. The water fountain is also of an unknown age, although it ought to be reusable if a customer can be found, or may be useful elsewhere within the Fort Leonard Wood DPW. If nothing else, this equipment should be recycled. The refrigerant in the water fountain’s compressor/condenser unit will have to be captured if this fixture is to be recycled.

Mechanical systems

There is a minimal amount of mechanical equipment and distribution in this building and therefore only a cursory survey was performed.

Heating equipment consists of 2 ceiling hung gas fired heaters servicing the warehouse area and one residential sized forced air furnace servicing the office and break areas. The BTU output of these units was not observable. All of this equipment ought to be reusable. A trailer mounted air conditioning / air handling unit is placed outside the building, but this will undoubtedly be removed prior to building removal activities.

Other recyclable material includes the following (quantities are rounded):

- Approximately 300 lbs of gas supply pipe
- Approximately 0.5 tons of sheet metal duct and vents.

Electrical systems

Only a cursory survey of electrical components was made, as copper conductor and metals will be recycled regardless of whether the building is removed by wrecking or deconstruction. The majority of the light fixtures should be reusable in utilitarian applications and in acoustic ceiling systems. The building includes the following electrical components.

- 108 4' 2-tube fluorescent ceiling-hung industrial type light fixtures
- 8 4-tube lay-in fluorescent ceiling light fixtures
- At least 60 pounds of recyclable copper conductor.
- At least 1.1 tons of recyclable conduit
- Other miscellaneous recyclables; main switches, load centers, circuit breaker boxes, etc

Conclusions

Building 2314 General Purpose Warehouse is an excellent candidate for deconstruction. Similar buildings have been successfully deconstructed at other Army installations and have yielded significant quantities of usable lumber. Wood framing and sheathing boards are the primary materials of interest. The building employs conventional wood framing and construction techniques, which lend themselves to disassembly. Roughly 80,000 BF of lumber materials (over 100 tons) would be available for recovery and reuse. Specific issues are as follows.

- Almost no leakage was evident throughout the building. The wood materials were all observed to remain sound. However, the insulation between rafters and studs prevented a complete observation of all framing and deck or sheathing materials.
- While bolted connections would make disassembly of the roof support members easier, the nailed connections should not inhibit recovery potential.
- The absence of extensive wall and ceiling finishes make the framing and deck or sheathing members easily accessible.
- The height and dimensions of this building would not preclude smaller contractors from participating in this project. While construction equipment could be applied to expedite the deconstruction process, this building type can also be disassembled member-by-member with hand tools, proceeding top-to-bottom and one structural bay at a time. Member dimensions are such that handling should present no extraordinary difficulties.
- The wood species is most likely a Southern Pine, although this is yet to be confirmed.
- As this was constructed as a utilitarian building, there is relatively little finish material that must be removed to access the lumber, even with the added office/break area. This finish material will likely be disposed of as debris.
- There are very few plumbing, mechanical or electrical components that must be removed to access the lumber.
- Pipe insulation was reported to not be asbestos. Aside from the inconvenience of removing it, there should be no hazard associated with the piping materials. No other asbestos was reported in this building. However, an asbestos survey would have to verify the presence of absence of asbestos from this building.
- Removing fluorescent lamps, mercury (Hg) switches, PCB containing ballasts, and other hazardous building materials will need to take place regardless of whether the building is wrecked or deconstructed.
- The original exterior siding and interior paints are certain to be lead-based. As the condition of siding material was not observable, the reuse potential is uncertain. While there is no federal level regulation that would prevent the transfer and resale of lead-base painted material, it may be prudent to dispose of the siding as debris, unless it is found to be a high grade material in excellent condition.
- Including multiple GP Warehouse buildings within the scope of one contract should greatly enhance the attractiveness of deconstruction.

DECONSTRUCTION CAPABILITIES IN CENTRAL MISSOURI

As discussed above, each of Buildings 2352, 2565 and 2314 would be good candidates for deconstruction from a material content perspective. None of these buildings have any features that would inhibit deconstruction and materials recovery. However, a successful building removal / deconstruction project will require the following:

- Full scope building removal services
- Services capable of recovering building materials in safe and cost effective manner
- Outlets and end use markets for recovered materials

Three scenarios are possible for building removal at Fort Leonard Wood.

- A demolition or environmental contractor would be selected through bidding or price proposal, and they would deconstruct the buildings, complete traditional demolition and environmental tasks, and find market outlets for the materials within their own workforce and organization.
- A demolition or environmental contractor would be selected through bidding or price proposal. They would perform traditional demolition and environmental tasks in-house, but would subcontract or develop a partnership for deconstruction and material recovery.
- A demolition or environmental contractor would be selected through bidding or price proposal. They would retain a deconstruction consultant to train the workforce and managers and possibly direct the deconstruction as well. They would deconstruct the buildings, complete traditional demolition and environmental tasks, and find market outlets for the materials within their own workforce and organization.

Any of these scenarios are viable. It is most likely that a contractor capable of removing buildings the scope of Building 2352, or multiple other larger WWII-era buildings, will be regional in their operations or will be from the larger metropolitan areas such as Kansas City or St. Louis. The quantity and quality of materials, primarily lumber, should attract interest from these markets and beyond.

A brief survey was performed to assess potential interest in participating in deconstruction projects at Fort Leonard Wood. The purpose of this survey was not to identify all prospective service providers or develop a bidders list, but to assess whether a pool of resources is or is not likely be available for projects. When speaking to commercial entities, such as contractors or reuse stores, a caveat was always given that this was a very preliminary assessment of interest, and no specific plans, procurement actions, or obligation by the government should be implied.

While there is deconstruction activity occurring in the St. Louis area, it generally serves the residential demolition market. There is a more robust deconstruction industry emerging in the Kansas City area.

The Kansas City MO Habitat for Humanity ReStore is one of the largest ReStores in the Habitat International network. As an affiliate of The Reuse People of America (TRP) they perform deconstruction on a routine basis. TRP is a non-profit organization with 13 affiliated deconstruction businesses throughout the U.S. Kansas City ReStore's typical business model is to partner with local demolition contractors and then acquire the materials. They have a pool of contractors with whom they work. While Fort Leonard Wood is beyond their typical market radius, they have indicated a willingness to accept materials (and possibly even pick them up) because of the quantity of materials available in Building 2352 and the potential for additional materials from future deconstruction projects. The Kansas City ReStore would probably not be willing to assume a prime contract for building removal but may be provide some services. The Kansas City ReStore, and other ReStores across the state could also serve as an outlet for the materials.

The Mid America Regional Council in Kansas City has initiated deconstruction training for contractors, and has developed a partnership with the Kansas City Kansas Community College for workforce development in deconstruction and building materials reuse. To date, approximately 40 commercial demolition contractors have received deconstruction training and over 100 individuals have or are taking deconstruction training. While the majority of these contractors operate in the Kansas City area, the scope of Building 2352 and the other WWII-era wood building removal requirement will certainly attract participation from throughout the state. As deconstruction contractors in Missouri require a demolition contractor's license, some of these contractors should be able to perform as prime contractors.

There is also an active deconstruction industry in Iowa, especially in the Davenport and Dubuque areas. The Iowa Department of Natural Resources has recently initiated a program directed toward deconstruction of larger commercial, institutional, and industrial buildings that have been abandoned and ownership has been assumed by municipalities in rural areas. Payment is based on waste diversion rates. Discussions with people familiar with the Iowa deconstruction infrastructure have identified contractors who would be willing and capable of working at Fort Leonard Wood.

Disposition of materials is typically the responsibility of the contractor. Deconstruction contractors almost always have their own material outlet (such as HfH ReStores), or have some ongoing arrangement with a used building materials business. Discussions with deconstruction and used building material businesses indicated there should be no problem finding outlets for Fort Leonard Wood lumber materials. The Building Materials Reuse Association directory includes 14 businesses in Missouri who deal in salvaged lumber, antique millwork or used building materials.

There is an on-line used building materials exchange service in Kansas City, Planet Reuse that maintains a network of demolition and deconstruction contractors, outlets for building materials, and architects and engineers looking for recovered materials to use in new projects. This firm finds potential buyers prior to a building's demolition so materials can be sold and removed without an interim transportation and retail step. Planet Reuse is willing and capable of marketing materials from Fort Leonard Wood buildings.

The value of the lumber will affect its marketability. The lumber material in question is a southern pine, although the exact species has not yet been analyzed. Heart Pine, Douglas fir, and selected other softwood species are valuable in the antique flooring and millwork industry. However, the more common pine species are not especially valuable for appearance purposes. That said, the lumber in the Fort Leonard Wood buildings is old growth lumber which is unavailable in the marketplace today. Pine can be used for flooring although it is somewhat soft for high wear applications. Other applications such as mouldings, beadboard, or v-groove planks can be attractive uses for old growth pine.

There will be a significant amount of wood material that is not reusable because pieces are of short length, are damaged during deconstruction, or have suffered damage or deterioration during the building's life. Wood scrap can be shredded for mulch or bio-fuel. The current assumption is that foundations may not be included within the contract scope, at least for the buildings built on a slab-on-grade. If foundation removal is included, concrete can be crushed for aggregate products and the reinforcing steel recycled. Wood and concrete can be crushed in a fixed facility off post, or on-site using portable equipment. The Construction Materials Reuse Association (CMRA) directory includes six construction and demolition material recycling firms in Missouri. In addition, Willard Asphalt in St. Robert accepts tear-off and new shingles for recycling at no cost. This should be a convenient and economical outlet for the shingles on Building 2314 and buildings with asphalt shingle roofs.

Recycling metals is common demolition industry practice and demolition contractors are familiar with recycling services in the Fort Leonard Wood area. Thus, there is no further discussion in this report.

In summary, a brief survey of in the Fort Leonard Wood region indicate there should be a sufficient pool of resources capable of deconstructing WWII-buildings and recovering materials for reuse. Lumber is the primary material of interest for reuse. Metals, asphalt shingles, and concrete will also be available for recycling. C&D recycling services are available throughout the state.

PROJECT PLANNING AND EXECUTION

Since this deconstruction feasibility assessment was conducted, plans for the subject buildings' demolition, and others, have progressed. The Corps of Engineers Facility Reduction Program (FRP) will remove 33 buildings In FY14, including the three subject buildings, plus a WWII-era Chapel. The FRP has awarded four regional Multiple Award Task Order Contracts (MATOCs). That is, multiple contractors within each regional MATOC compete for tasks. The FY14 task for Fort Leonard Wood will include building removal tasks, as well as surveys, hazardous material removal and others, and will be competitively bid as one Task among the regional MATOC contractors.

The FY14 FRP Task Order will include demolition of the subject buildings. In this case, the FRP administrators are reluctant to use the word "deconstruction" because they feel it implies an extremely deliberate, labor intensive, manual removal of buildings member-by-member. However, they understand Fort Leonard Wood's objective of recovering materials for reuse rather than mechanical wrecking. Their intent is to pursue a "deconstruction" approach without using the term "deconstruction."

As described in Chapter X, there are several issues to which attention must be paid to successfully execute such a project. While not fundamentally different from a conventional demolition project, the on opportunities to recover and reuse materials can be significant.

References

Resources are available within the Corps of Engineers library of guidance documents. Applicable to Fort Leonard Wood's facility removal requirements are the following:

PTWB 1-200-23 *Guidance for the Reduction of Construction and Demolition Waste through Reuse and Recycling* (see http://www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_1_23.pdf) . This PWTB provides alternative approaches for removing buildings, example contract provisions, and project specifications.

PWTB 1-200-120 *Opportunities to Increase Construction and Demolition Waste Diversion* (see http://www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_1_23.pdf) . This PWTB provides lessons-learned from recent building removal projects and recommendations for improving building removal practices and C&D waste reduction performance.

Project Description

The terms "demolition" and "deconstruction" need not be positioned as polar opposites. Deconstruction is one method of demolition. Landfill disposal, salvage, recycling, and resale for reuse are methods for the disposition of materials. In practice, deconstruction, salvage, demolition, and recycling can all be performed when removing a building.

As there is an aversion to the term "deconstruction," the terms "demolition" or "building removal" would be appropriate for the purposes of this project

Regardless of the terminology used, Fort Leonard Wood's objectives are to remove the building in an efficient, economical, and safe fashion while recovering as much of the building's materials for reuse as practical and minimizing landfill disposal. Thus, "demolition" must not imply to the contractor the removal of the building by destructive means without regard to material recovery and reuse.

Note, however, that the Unified Facilities Guide Specification (UFGS) 02 41 00 is entitled "[Demolition] [and] [Deconstruction]." This specification addresses either or both methods of building removal. Therefore, the term "deconstruction" is not alien to Army or other Federal Agencies.

Outreach

In order to meet Fort Leonard Wood's expectations, the contractor must apply to the project the necessary services to remove the building(s) efficiently and economically, in a safe manner, and extracting as much useable material as practical. If that expertise does not reside in-house with the MATOC contractors, services are available in the region (Missouri, southern Iowa) to supplement the contractor's capabilities. These include deconstruction services, building materials brokers, recovered building materials resale businesses, and training and consulting services to provide project planning and execution guidance. ERDC-CERL will provide a list of referrals to FRP and Fort Leonard Wood personnel.

Conducting an on-site "workshop" has proven very effective in the past. The purpose is to bring prospective contractors and other necessary services together in one place, at one time. While the Government cannot assign subcontractors to prime contractors, they can provide a forum for information exchange. Doing so also provides an opportunity to clarify Fort Leonard Wood's expectations for the project to all prospective participants. If a pre-bid or pre-proposal meeting or job walk is held at Fort Leonard Wood, this would be the ideal opportunity to bring the prospective participants together.

Previous deconstruction experience suggests outlets for materials can be found on-post. Scrap lumber, windows, doors and landscape materials have frequently been requested by troop units for self-help projects or construction of training aids. A survey of other Fort Leonard Wood offices and agencies is suggested as identifying on-post reuse opportunities.

Special outreach efforts for recycling metals and scrap wood should not be necessary as these practices are common within the demolition industry. The Army's position that incineration does not count toward diversion, even if applied to waste-to-energy bio purposes, must be clarified to contractors and C&D recyclers.

Scope of the task

If possible, separating the demolition tasks (for which material recovery is an objective) from the other study or survey, abatement, and demolition (by wrecking) tasks for a 30-some building demolition task has advantages. Doing so places 100% of the contractor's attention on the demolition tasks. It avoids the risk of a contractor under-performing because demolition represents only a small part of a larger contract's dollar value.

Materials available in the buildings

Description of the types and quantities materials available for recovery and reuse in the Scope serves two purposes. It informs bidders of the potential value of the building's materials, and it alerts bidders that the Army is aware of the potential value. Thus, bidders are expected to take into account material value when developing their bid. In Building 2352 alone, there is roughly 150,000 Board Feet of lumber available. This figure does not include blocking, cripples, braces, and other members fewer than 6 feet long. There is also in excess of 20 tons of metals in Building 2352. This information is provided as information only to the prospective bidders and is not intended to represent a detailed quantity take-off. The Chapel and warehouse building also provide the opportunity of significant lumber recovery.

Material ownership

As is common practice, the contractor is deeded ownership of all materials, with the exception of any the Government desires to retain. The origins of this provision relate to the contractor assuming responsibility for proper disposal. However, benefits can also accrue to the contractor. All revenue from recovering and recycling materials and cost avoidance through diverting materials from landfill disposal accrues to the contractor. All expenses in landfill disposal are borne by the contractor.

Bidder qualifications

This task will be awarded on a Competitive Bid basis. The lowest-priced, qualified bidder will be awarded the contract. The bid documents, therefore, must include a bidder qualification requirement. This should include demonstrated capabilities and experience in removing buildings with the purpose of recovering materials for reuse. Qualifications include example projects, materials recovered and recovery rates, and disposition of the materials (i.e. outlets, markets) . Other services retained by the contractor should, likewise, display capabilities and experience within the scope of their services.

Bid schedules / Options

One method of increasing diversion rates is to include bid options in the bid schedule for successively higher diversion rates above the minimum 58% requirement. Where materials recovery for reuse is the preference, the bid options can incorporate line items for progressively higher rates, 58-65%, 66-75%, up to 95%, for example. If a Best Value contract will not be offered, bid options may be the next best method to balance performance and price.

C&D waste management / Waste reduction plan

A C&D Waste Management Plan is (or should be) standard with any construction or demolition contract. Beyond conformance with waste disposal regulations, however, this plan should also address building removal methods, materials recycled and recovered for reuse, debris materials, subcontractors or services applied, material outlets or markets applied, and recycling and disposal facilities. The plan should also include performance monitoring, recording, and reporting processes. ERDC-CERL can provide sample C&D Waste Management/Reduction Plans to FRP and Fort Leonard Wood personnel.

This plan should be required as a Submittal, and reviewed and approved by the Government prior to issuing a Notice to Proceed. If it is apparent the contractor is diligently applying the resources available to them, the plan is reasonable given the project's requirements and conditions, and will achieve the highest reuse and diversion rate practical, then the Government approves it and issues the NTP. If it is apparent the contractor is underutilizing available resources, is questionable in the contractor's ability to execute, or otherwise suggests satisfactory results may not be forthcoming, the Government can return the plan for revision before issuing the NTP.

Once the plan is approved, it becomes part of the Contract and is applied (i.e. enforced) as such.

Diversion reporting / Recording requirements

C&D materials recycling and reuse performance should be monitored, recorded, and reported similar to safety, regulatory compliance, and other topics throughout the project's duration.

The MILCON RFP cites a requirement to report C&D diversion performance every 30 days. In the case of this Fort Leonard Wood demolition project, this is too long a period of time between reports. A building will be gone and the site restored in that time. The frequency of reporting should allow evaluation and readjustment to address any performance issues occurring during the project's execution. Otherwise, reporting will always be after-the-fact cannot contribute to improving performance.

Quality control / Quality assurance

C&D materials reuse and diversion performance should be integrated within the QC/QA requirements.

Demolition / Deconstruction task

The demolition specification language should be similar to a conventional demolition project, such as, UFGS 02 41 00 [Demolition] [and] [Deconstruction].

All occupational safety requirements must be observed regardless of the methods used to remove the building. This includes exposure to lead. *

> **For the Government's information, previous deconstruction experience is that personal monitoring has always resulted in a negative assessment, and therefore respiratory protection can be re-*

duced. However, good housekeeping practices with respect to the spread of lead-based paint chips must be observed.

Diversion criteria must be included. As a minimum, a 58% diversion rate must be specified. The expectation that the majority of lumber is expected to be recovered in a reusable condition must be included with this criterion. Exterior siding and other wood materials that are lead-based painted can be excluded. Recycling of metals is assumed, although there are mechanical components that were still serviceable and could be recovered for reuse.

A lumber recovery rate of 75% is usually realistic, accounting for breakage, deterioration, short pieces, etc. However, it may be more prudent to not place a minimum recovery-for-reuse percentage on any individual material, and allow the 58% overall criterion to prevail. Lumber will constitute the majority of the building's mass, as the foundation and slab will not be removed, and are not counted. Recycling wood materials into bio-fuel will not count as diversion. Therefore, the contractor will be compelled to secure reuse outlets for the reusable lumber materials. It is suggested, therefore, that the contractor's C&D Waste Management/Reduction Plan, as approved by the Government, dictate the rate of lumber recovery for reuse to be applied as the contract requirement. If, however, it is felt a definitive percentage for wood materials is desired, a rate of 65% of the reusable wood materials in-place in the building should be achievable. As discussed above, bid options for recovery rates higher than 58% can also be incorporated into the bid schedule.

The contractor should be entitled to take lead-based painted materials as long as will handle and process these materials consistent with occupational and consumer safety standards.

It may be useful to the contractor to be able to process and hold recovered materials at Fort Leonard Wood prior to transporting them to outlets. The contractor should be entitled to use a vacant building to be demolished for these purposes until it is demolished (Building 2565, for example). If Fort Leonard Wood has any vacant buildings that can be useful to the contractor as the last building is being demolished, it is suggested Fort Leonard Wood makes this opportunity available to the contractor. The appropriate conditions of time allowed the contractor for their occupancy, condition of the building upon completion, etc, must be included in this provision.

Project close-out

Project close-out should proceed as with any other demolition project. Ensure the Environmental Division personnel responsible for entering data into the SWAR are provided with the required information.

Publicity / Press coverage

Past “deconstruction” projects have typically drawn favorable attention from the public. While not a contract requirement, project personnel should be open to positive publicity and cooperation with media.

Appendix E: Building 2352 Scope of Work for Demolition

REFERENCES

PTWB 1-200-23 *Guidance for the Reduction of Construction and Demolition Waste through Reuse and Recycling* (see http://www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_1_23.pdf) . There are example approaches, contract provisions, and specifications offered in this document.

PWTB 1-200-120 *Opportunities to Increase Construction and Demolition Waste Diversion* (see http://www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_1_23.pdf) . Lessons learned and improvements to building removal practices are offered in this document.

PROJECT DESCRIPTION

The terms “demolition” and “deconstruction” need not be positioned as polar opposites. Deconstruction is one method of demolition. In practice, deconstruction, salvage, demolition, and recycling can all be performed when removing a building.

For the purposes of this project, the term “demolition” or “building removal” would be appropriate if there is an aversion to the term “deconstruction.”

Regardless of the terminology used, Fort Leonard Wood’s objectives are to remove the building in an efficient, economical, and safe fashion while recovering as much of the building’s materials for reuse as practical and minimizing landfill disposal. Thus, “demolition” must not imply to the contractor the removal of the building by destructive means without regard to material recovery and reuse.

Note, however, that UFGS 02 41 00 is entitled “[Demolition] [and] [Deconstruction],” addressing either or both methods of building removal. Therefore, the term “deconstruction” is not alien to Army or other Federal Agencies.

OUTREACH

In order to meet the customer’s expectations, the contractor must apply to the project the necessary services to remove the building(s) efficiently and economically, in a safe, and extracting as much useable material as practical. If that expertise does not reside in-house services are available in the region (Missouri, southern Iowa) to supplement the contractor’s capabilities. These include deconstruction services, building materials brokers, recovered building materials resale businesses, and training and consulting services to provide project planning and execution guidance. ERDC-CERL will provide a list of referrals.

Conducting an on-site “workshop” has proven very effective in the past. The purpose is to bring prospective contractors and other necessary services together in one place, at one time. While the Government cannot assign subcontractors to prime contractors, they can provide a forum for information exchange. Doing so also provides an opportunity to clarify Fort Leonard Wood’s expectations for the project to all prospective participants. If a pre-bid or pre-proposal meeting or job walk is held, this would be the ideal opportunity time to bring the prospective participants together.

Previous deconstruction experience suggests outlets for materials can be found on-post. Scrap lumber, windows, doors and landscape materials have frequently been requested by troop units for self-help projects or construction of training aids. A survey of other Fort Leonard Wood offices and agencies is suggested as identifying on-post reuse opportunities.

Special outreach efforts for recycling metals and scrap wood should not be necessary as these practices are common within the demolition industry. The Army’s position that incineration does not count toward diversion, even if applied to waste-to-energy bio purposes, must be clarified to contractors and C&D recyclers.

SCOPE OF CONTRACT

If possible, separating the demolition tasks (for which material recovery is an objective) from the other study or survey, abatement, and demolition (by wrecking) tasks for a 40-some building demolition task has advantages. Doing so places 100% of the contractor's attention on the demolition tasks. It avoids the risk of a contractor under-performing because demolition represents only a small part of a larger contract's dollar value.

MATERIALS AVAILABLE IN THE BUILDING

Description of the types and quantities materials available for recovery and reuse in the Scope serves two purposes. It informs bidders of the potential value of the building's materials, and it alerts bidders that the Army is aware of the potential value. Thus, bidders are expected to take into account material value when developing their bid. In Building 2352, there is roughly 150,000 Board Feet of lumber available. This figure does not include blocking, cripples, braces, and other members fewer than 6 feet long. There is also in excess of 20 tons of metals in this building. This information is provided as information only to the prospective bidders and is not intended to represent a detailed quantity take-off.

MATERIAL OWNERSHIP

As is common practice, the contractor is deeded ownership of all materials, with the exception of any the Government desires to retain. All revenue from recovering and recycling materials and cost avoidance through diverting materials from landfill disposal accrues to the contractor. All expenses in landfill disposal are borne by the contractor.

BIDDER QUALIFICATIONS

The bid documents should include a bidder qualification requirement. This should include demonstrated capabilities and experience in removing buildings with the purpose of recovering materials for reuse. Qualifications include example projects, materials recovered and recovery rates, and disposition of the materials (i.e. outlets, markets) .

Other services retained by the contractor should, likewise, display capabilities and experience within the scope of their services.

BID SCHEDULE / OPTIONS

One method of increasing diversion rates is to include bid options in the bid schedule for successively higher diversion rates above 58%. Where materials recovery for reuse is the preference, the bid options can incorporate a reuse rate. If a Best Value contract will not be offered, bid options may be the next best method to balance performance and price.

C&D WASTE REDUCTION PLAN

A C&D Waste Management Plan is (or should be) standard with any construction or demolition contract. Beyond conformance with waste disposal regulations, however, this Plan should also address building removal methods, materials recycled and recovered for reuse, debris materials, subcontractors or services applied, material outlets or markets applied, and recycling and disposal facilities. The Plan should also include performance monitoring, recording, and reporting processes. ERDC-CERL can provide sample C&D Waste Management/Reduction Plans.

This Plan should be required as a Submittal, and reviewed and approved by the Government prior to issuing a Notice to Proceed. If it is apparent the contractor is diligently applying the resources available to them, the plan is reasonable given the project's requirements and conditions, and will achieve the highest reuse and diversion rate practical, then the Government approves it and issues the NTP. If it is apparent the contractor is underutilizing available resources, is questionable in the contractor's ability to execute, or otherwise suggests satisfactory results may not be forthcoming, the Government can return the Plan for revision before issuing the NTP.

Once the Plan is approved, it becomes part of the Contract and is applied (i.e. enforced) as such.

DIVERSION RECORDING / REPORTING REQUIREMNTS

C&D materials recycling and reuse performance should be monitored, recorded, and reported similar to safety, regulatory compliance, and other topics throughout the project's duration.

The MILCON RFP cites a requirement to report C&D diversion performance every 30 days. In the case of the Fort Leonard Wood demolition project, this is too long a period of time between reports. A building will be gone and the site restored in that time. The frequency of reporting should allow evaluation and readjustment to address any performance issues occurring during the project's execution. Otherwise, reporting will always be after-the-fact cannot contribute to improving performance.

QUALITY CONTROL / QUALITY ASSURANCE

should include C&D materials reuse and diversion performance should be integrated within the QC/QA requirements.

DEMOLITION / DECONSTRUCTION TASK

The demolition specification language should be similar to a conventional demolition project, such as, UFGS 02 41 00 [Demolition] [and] [Deconstruction].

All occupational safety requirements must be observed regardless of the methods used to remove the building. This includes exposure to lead. *

**For the Government's information, previous deconstruction experience is that personal monitoring has always resulted in a negative assessment, and therefore respiratory protection can be reduced. However, good housekeeping practices with respect to the spread of lead-based paint chips must be observed.*

Diversion criteria must be included. As a minimum, a 58% diversion rate must be specified. The expectation that the majority of lumber is expected to be recovered in a reusable condition must be included with this criterion. Exterior siding and other wood materials that are lead-based painted can be excluded. Recycling of metals is assumed, although there are mechanical components that were still serviceable and could be recovered for reuse.

A lumber recovery rate of 75% is usually realistic, accounting for breakage, deterioration, short pieces, etc. However, it may be more prudent to not place a minimum recovery-for-reuse percentage on any individual material, and allow the 58% overall criterion to prevail. Lumber will constitute the majority of the building's mass, as the foundation and slab will not be removed, and are not counted. Recycling wood materials into bio-fuel will not count as diversion. Therefore, the contractor will compelled to secure reuse outlets for the reusable lumber materials. It is suggested, therefore, that the contractor's C&D Waste Management/Reduction Plan, as approved by the Government, dictate the rate of lumber recovery for reuse to be applied as the contract requirement. If, however, it is felt a definitive percentage for wood materials is desired, a rate of 65% of the reusable wood materials in-place in the building should be achievable. As discussed above, bid options for recovery rates higher than 58% can also be incorporated into the bid schedule.

The contractor should be entitled to take lead-based painted materials as long as will handle and process these materials consistent with occupational and consumer safety standards.

It may be useful to the contractor to be able to process and hold recovered materials at Fort Leonard Wood prior to transporting them to outlets. The contractor should be entitled to use a vacant building to be demolished for these purposes until it is demolished (Building 2565, for example). If Fort Leonard Wood has any vacant buildings that can be useful to the contractor as the last building is being demolished, it is suggested the installation makes this opportunity available to the contractor. The appropriate conditions of time, condition of the building upon completion, etc, must be included in this provision.

PROJECT CLOSE-OUT

Project close-out should proceed as with any other demolition project. Ensure the Environmental Division personnel responsible for entering data into the SWAR is provided with the required information.

PUBLICITY/PRESS COVERAGE

Past “deconstruction” projects have typically drawn favorable attention from the public. While not a contract requirement, project personnel should be open to positive publicity and cooperation with media.

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14. ABSTRACT
The Army focused its organizational sustainability on the development of Net Zero waste, energy, and water at its installations. Fort Leonard Wood faces constraints on critical resources. As part of its strategic sustainability vision, Fort Leonard Wood seeks to meet Army Net Zero objectives.

The objective of this project was to develop an integrated portfolio of cost-effective and mission-appropriate strategies, approaches, and technologies to help Fort Leonard Wood implement its Net Zero strategic vision for energy, water, and waste.

The U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) was consulted to help Fort Leonard Wood identify and evaluate strategies, methods, and technologies to support the Army Net Zero objectives. ERDC-CERL performed assessments to baseline energy, water, and waste systems at Fort Leonard Wood. Because these systems are highly interrelated, they were best evaluated concurrently and optimized in an integrated effort.

Energy, water, and waste teams estimated changes in requirements, population, energy and water use, and waste generation over a 25 year time period. Each team then established alternatives to show how improved practices, sustainable development and high performance buildings could reduce waste generation, energy, and water use.

15. SUBJECT TERMS
Net Zero energy/water/waste, sustainability, Fort Leonard Wood, MO

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